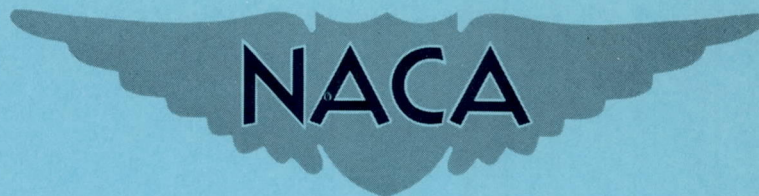


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RESEARCH MEMORANDUM

PERFORMANCE OF PURE FUELS IN SINGLE J33 COMBUSTORS

II - HYDROCARBON AND NONHYDROCARBON FUELS

By Arthur L. Smith and Jerrold D. Wear

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Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE
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SUMMARY

Performance investigations of 13 fuels - five hydrocarbons, four oxygenated hydrocarbons, and four substituted hydrocarbon-type fuels - were conducted in a single tubular turbojet combustor in order to determine a possible relation between combustor performance and fuel properties. The fuels tested were isooctane, *n*-pentane, isopentane, 2,2-dimethylbutane, 2-pentene, methanol, propylene oxide, diethyl ether, carbon disulfide, acetone, butylsilane, acrylonitrile, and acrolein.

Combustor temperature rise and combustion efficiency were determined at air-flow rates of 0.6, 0.8, 1.0, and 1.3 pounds per second, inlet-air total temperatures of 40° and 200° F, and a range of heat-input values from about 100 to 750 Btu per pound of air. Combustor-inlet total pressure was held constant at 14.3 inches of mercury absolute. Combustor blow-out limits were determined for the majority of the fuels over this range of test conditions.

At a heat-input value of 250 Btu per pound of air, a tentative correlation was obtained between combustion efficiency and the parameter $u_x/L_v^{1/3}$, where u_x is the maximum burning velocity at atmospheric pressure and temperature and L_v is the latent heat of vaporization at the normal boiling point. The data also indicated an approximate trend toward an increase in maximum temperature rise across the combustor with increase in maximum burning velocity.

The general performance order among the fuels was: butylsilane, carbon disulfide, and propylene oxide - highest; acrolein, acrylonitrile, 2-pentene, diethyl ether, *n*-pentane, isooctane, and acetone - intermediate; isopentane, 2,2-dimethylbutane, and methanol - lowest.

INTRODUCTION

Research is being conducted at the Lewis laboratory to determine design procedures and principles required for the development of high-performance turbojet combustors. One phase of this research program is concerned with a study of the importance of such individual processes as evaporation, ignition, reaction, and quenching that occur in over-all combustion. Because of the complexity of turbojet combustion, one method of studying the individual processes would be to establish a possible relation among combustor performance and selected physical and/or fundamental combustion properties of the fuel. Thus, any relation obtained may indicate the relative importance of the individual processes.

Studies of the relation among combustor performance characteristics and properties of pure fuels are presented in references 1 and 2. In reference 1, combustion efficiency is related to maximum burning velocity and minimum spark-ignition energy. A single pure fuel isooctane (2,2,4-trimethylpentane) was used, and the range in the fundamental combustion properties was obtained by varying the oxygen content of the inlet oxygen-nitrogen mixture. In reference 2, the range in fundamental combustion properties of the fuel was obtained by varying the fuel type. An approximate relation between combustor performance and maximum burning velocity was indicated but, because the range of fuel properties was small, no conclusive relation could be established. Consequently, additional investigations with fuels having a wider range in physical and fundamental combustion properties were recommended.

The full-scale single-combustor performance data reported herein are a continuation of data reported in reference 2. Thirteen pure fuels, including five hydrocarbons, were selected because of their wide range in physical and fundamental combustion properties. The combustor test conditions included one inlet-air pressure, two inlet-air temperatures, and four inlet-air mass-flow rates. The inlet-air pressure condition, 14.3 inches of mercury absolute, was sufficiently low to be considered severe from the standpoint of combustion. The two inlet-air temperatures (40° and 200° F) differed by 160° F. The air mass-flow rate was varied from 0.6 to 1.3 pounds per second, resulting in a considerable range of severity. A variable-area fuel nozzle (similar to the type described in ref. 2) was used in order to minimize variations in fuel atomization characteristics.

The physical and fundamental combustion properties considered were normal boiling point, heat content at the spontaneous ignition temperature, latent heat of vaporization, spontaneous ignition temperature, flammability range, minimum spark-ignition energy, and maximum burning velocity. The combustor performance parameters used to compare the fuels were maximum combustor temperature rise and combustion efficiency at a heat-input value of 250 Btu per pound of air. The combustion

performance characteristics of the fuels are presented, and an attempt to establish a relation between fuel properties and combustor performance parameters is made.

FUELS

The fuels in the present investigation represent three classes; (1) hydrocarbon, (2) oxygenated hydrocarbon, and (3) substituted hydrocarbon. Laboratory inspection data for these fuels together with physical data from the literature for the pure materials are presented in table I. The physical data for the pure fuels were compared with laboratory test data in order to obtain the listed estimates of fuel purity. The purity of the fuels was at least 95 mole percent except for 2-pentene, which had a purity of about 93 percent. Some fundamental combustion data for these fuels are also included in table I.

APPARATUS AND INSTRUMENTATION

A diagram of the general arrangement of the single J33 combustor and the auxiliary equipment is shown in figure 1. Air flow to the combustor was measured by a square-edge orifice plate installed according to A.S.M.E. specifications and located upstream of all regulating valves. The combustor inlet-air quantities and pressures were regulated by remote-controlled valves in the laboratory air-supply and exhaust systems. The air supplied to the combustor had a dew point of either -20° or -70° F.

A diagrammatic cross section showing the combustor and its auxiliary ducting, the position of the instrumentation planes, and the location of temperature- and pressure-measuring instruments in the instrumentation planes is presented in figure 2. Thermocouples and total-pressure tubes in each instrumentation plane were located at centers of equal annular area. Construction details of the temperature- and pressure-measuring instruments are shown in figure 3.

The two fuel systems used in the present investigation are illustrated diagrammatically in figure 4. In each system, nitrogen pressure was used to force the fuel from the fuel storage accumulators or tanks to the combustor. The systems were flushed with isooctane and then purged with nitrogen after the completion of each fuel run. This was done in order to free the systems of contaminants and of air.

In the system shown in figure 4(a), valves were installed to permit separate or parallel operation of the accumulators. Rubber bladders

were installed in the accumulators to separate the nitrogen and the fuel, preventing possible dissolution of the nitrogen in the fuel. The fuel-flow rate was determined by means of calibrated rotameters located downstream of the accumulators. This system was used for the following fuels: isooctane; isopentane; n-pentane; 2,2-dimethylbutane; 2-pentene; and methanol. Because of the corrosive nature of propylene oxide, diethyl ether, carbon disulfide, and acetone, the bladders were removed from the accumulators during tests on these fuels.

The system shown in figure 4(b) was designed to permit the measurement of the fuel flow by means of a time - weight-flow method in order to eliminate the necessity of open-air calibration of rotameters for the toxic fuels: acrolein, acrylonitrile, and butylsilane. This system is different from that illustrated in figure 4(a) in that there were no bladders in the fuel tanks, and the tanks could not be used independently of one another. The fuel flow was determined by measuring the time rate of change in weight of the tanks. Small fuel tanks were used instead of the large accumulators in order to decrease the fuel-supply system-tare weight for a more accurate fuel-flow measurement.

A variable-area fuel nozzle was used in this investigation in order to minimize the variation in nozzle pressure drop with change in fuel flow. A detailed description of this fuel nozzle is given in reference 2.

PROCEDURE

The combustor performance of the majority of the fuels was determined at the following inlet-air conditions with inlet-air total pressure held constant at 14.3 inches of mercury absolute:

Inlet-air mass flow, lb/sec	Inlet-air velocity, ^a ft/sec	
	Inlet-air total temperature, °F	
	40	200
0.6	60	79
.8	80	105
1.0	100	132
1.3	130	173

^aBased on combustor maximum cross-sectional area of 0.267 sq ft measured $12\frac{1}{2}$ in. downstream of section B-B (fig. 2).

Tests were limited with acrylonitrile, acrolein, butylsilane, and carbon disulfide because of the small quantity of these fuels available.

The desired combustor inlet-air test conditions were established at a low fuel-flow rate (about 200° F combustor temperature rise), and data recorded when conditions were stabilized. Fuel flow was then increased to obtain increments in combustor temperature rise of about 200° F. This procedure was continued until rich blow-out occurred or the maximum capacity of the facilities was attained. The ignition plug was de-energized during operation.

In order to determine the reproducibility of the test results, iso-octane fuel was investigated periodically over the testing period. In addition to the routine checking of the iso-octane data, the combustion chamber was periodically cleaned to ensure freedom from deposits which might affect performance.

CALCULATIONS

Combustor temperature rise. - The combustor temperature rise was determined as the increase in gas temperature from section B-B to C-C (fig. 2). The temperature at B-B was the average indication of the two iron-constantan thermocouples; the temperature at C-C was the arithmetical average indication of the 16 chromel-alumel thermocouples. The indicated thermocouple readings were taken as true values of the total temperature.

Combustion efficiency. - Combustion efficiency was defined as

$$\frac{\text{Actual enthalpy rise across combustor}}{\text{Heating value of fuel} \times \text{fuel flow}}$$

The equations and charts of reference 3 were used to determine combustion efficiency for the hydrocarbon fuels. Additional information concerning the use of these charts is presented in reference 2. The method, however, is restricted to fuels containing only hydrogen and carbon.

The combustion efficiency for the oxygenated hydrocarbons was determined by assuming the products of combustion to be carbon dioxide and water vapor; for example,



The combustion efficiency for the substituted hydrocarbons was determined by assuming the following reactions to occur:

CS_2 (carbon disulfide) + excess air $\rightarrow \text{CO}_2 + \text{SO}_2 + \text{excess air}$

$\text{C}_3\text{H}_3\text{N}$ (acrylonitrile) + excess air $\rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{N}_2 + \text{excess air}$

$\text{C}_4\text{H}_9\text{SiH}_3$ (butylsilane) + excess air $\rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{SiO}_2 + \text{excess air}$

The enthalpy rise of the oxygenated and substituted hydrocarbon fuels was determined as the difference in the enthalpy of the products of combustion at the exhaust temperature and of the inlet temperature. Enthalpy data used to compute the enthalpy rise are from references 4, 5, and 6; heating values of the fuels are presented in table I (lower heat of combustion) along with physical and fundamental combustion data obtained experimentally and from references 7 to 27.

The inlet-air total-pressure values were obtained from the 12 total-pressure tubes (section A-A, figs. 2 and 3), which were connected to a single manifold.

In order to place the performance of the various fuels on a comparable basis, heat input (product of fuel-air ratio and lower heat of combustion of the fuel) was used in place of fuel-air ratio as one of the independent variables.

RESULTS

Combustor performance data for five hydrocarbon, four oxygenated hydrocarbon, and four substituted hydrocarbon fuels obtained in a single J33 combustor are presented in table II. Figures 5 to 17 present relations among heat input, combustor temperature rise, and combustion efficiency for each of the fuels investigated at each of the various operating conditions. Combustor blow-out points are also noted in these figures.

Throughout the test program periodic checks on the performance of the combustor were made using isooctane as a reference fuel. The deviation in combustion efficiency and combustor temperature rise for various heat-input values is shown in figure 5. These data were obtained over a period of 6 months, during which time the combustor was disassembled several times. The average percentage deviation of the combustion efficiency of individual data points from the curve faired through all the data was ± 1 percent. The maximum deviation of the combustion efficiency was 4 percent. Consequently, differences above 2 percent among fuels may generally be considered as real differences, while differences below 2 percent fall within the reproducibility range. Blow-out points could be checked closely at the time obtained; however, comparable data obtained over a period of time varied to some degree.

The data of figures 5 to 17 indicate, in general, a progressive increase in temperature rise with heat input up to the rich blow-out point. However, at some of the inlet conditions, the maximum temperature rise obtained with isooctane, acetone, and diethyl ether occurred at heat-input values lower than that required for rich blow-out. The heat-input values at the rich blow-out points decreased, in general, with an increase in inlet-air temperature and inlet-air mass-flow rates. Rich blow-out points were obtained with all hydrocarbon fuels (figs. 5 to 9), acetone (fig. 11), and diethyl ether (fig. 12) at all combustor-inlet conditions. For the other fuels, rich blow-out points were not obtained at some combustor-inlet conditions because of limitations imposed by the test facilities. These points are indicated on the figures as facility limited and are identified along with rich blow-out points by an assigned symbol.

Maximum temperature rise tended to increase with increase in inlet-air temperature at the lower air-flow rates. However, at the higher air-flow rates, the reverse of this trend is evident. Maximum temperature rise generally decreased with increase in air-flow rate.

Combustion efficiency, in general, decreased with increases in inlet-air mass-flow rate for all fuels except propylene oxide (fig. 13), acrolein (fig. 14), carbon disulfide (fig. 16), and butylsilane (fig. 17). For these fuels, combustion efficiency remained substantially constant with increases in inlet-air mass-flow rate. An increase in inlet-air temperature improved combustion efficiency slightly for the majority of the fuels at all inlet-air mass-flow rates.

The highest combustion efficiency and combustor temperature rise observed, approximately 97 percent and 2254° F, respectively, were obtained with propylene oxide and butylsilane fuel at a low inlet-air mass-flow rate. This temperature-rise value represents a facility limitation. During tests with butylsilane, flocculent particles, possibly products formed by hydrolysis, were observed in the rotameter. After the completion of tests with this fuel, a collection of these particles was found in the fuel filter. When the combustor was disassembled, a heavy silicon dioxide coating was observed on the fuel nozzle, the combustor, and the exhaust thermocouples. A photograph of the fuel nozzle and combustion chamber showing the silicon dioxide deposits is presented in figure 18. The deposit at the base of the fuel nozzle and on the dome of the liner was a fine powder (fig. 18(a)) in contrast to the coarse granular deposits (fig. 18(b)) observed on the nozzle tip, the inner liner wall, and the exhaust thermocouples (not shown). The combustor-outlet temperature data obtained with this fuel are probably lower than the actual gas temperature because of the insulating effect of the heavy deposits formed on the exhaust thermocouples.

DISCUSSION

The objective of the investigation reported herein was to determine a possible relation between combustor performance and physical or fundamental combustion properties of the fuels. Two representative combustor performance parameters were selected for making comparisons among the fuels. The first parameter chosen was combustion efficiency at a heat-input value of 250 Btu per pound of air, the maximum heat-input value at which data were available for all fuels. Combustion efficiency at a particular heat-input value is related to the fuel consumption of the engine. The second performance parameter, maximum temperature rise through the combustor, is related to the altitude operational limits of the turbojet engine.

Combustion Efficiency

A comparison of combustion efficiencies obtained with each fuel at a heat-input value of 250 Btu per pound of air is presented in figure 19. An increase in inlet-air mass-flow rate and, consequently, air velocity, usually tended to decrease combustion efficiency and to increase the variation in combustion efficiency with fuel type. In general, the fuels providing the highest and the lowest combustion efficiency were butylsilane and methanol, respectively. The differences between methanol and butylsilane varied from approximately 30 to 60 percent at the different operating conditions. The general performance order of the remaining fuels was carbon disulfide, propylene oxide, acrolein, acrylonitrile, 2-pentene, diethyl ether, *n*-pentane, isooctane, acetone, isopentane, and 2,2-dimethylbutane. From figure 19, it is evident that the performance order of the fuels changed somewhat with combustor operating conditions; consequently, no single correlation between combustion efficiency and fuel properties is likely to be effective over the entire combustor operating range. It is noted that the high performance fuels were less affected by changes in inlet-air mass-flow rates.

Comparison of combustion efficiency with physical fuel properties. - Some physical properties of the fuel that may be considered to have possible effects on combustor performance are (a) latent heat of vaporization, (b) boiling point of the fuel, and (c) heat content at the spontaneous ignition temperature. An increase in the magnitude in any one of these properties might be expected to reduce the rate of vaporization and, consequently, impede the over-all combustion process. However, comparisons of these properties (see table I) with the combustion efficiencies of the fuels described in the preceding section indicate no consistent relation.

Comparison of combustion efficiency with fundamental combustion fuel properties. - Some fundamental combustion properties of fuels that

may be considered to have possible effects on combustor performance are (1) spontaneous ignition temperature, (2) flammability range, (3) minimum spark-ignition energy, and (4) maximum burning velocity. An increase in flammability range or maximum burning velocity, or a decrease in minimum ignition energy or spontaneous ignition temperature might be expected to effect increases in the rate of the combustion process.

Attempts to relate spontaneous ignition temperature and flammability range with combustion efficiency were unsuccessful. There was a slight trend toward a decrease in combustion efficiency with decrease in flammability range and increase in spontaneous ignition temperature; however, the scatter of the data was greater than could be tolerated for correlating performance.

Maximum burning velocity of fuels, with the exception of carbon disulfide, can be correlated approximately with minimum spark-ignition energy (refs. 7 and 8). Accordingly, if a correlation between combustor performance and maximum burning velocity is obtained, a similar correlation between combustion efficiency and minimum spark-ignition energy would be expected. In view of the greater inherent errors associated with determination of minimum spark-ignition energies, the combustor performance data for the various fuels were considered in terms of the maximum burning velocity.

In figure 20, combustion efficiency at a heat-input value of 250 Btu per pound of air is plotted against maximum burning velocity (cm/sec). The inlet-air mass-flow rate and inlet-air temperature are 1.0 pound per second and 40° F, respectively. Interpolated data from figure 19 are included for butylsilane, acrylonitrile, acrolein, and carbon disulfide. Also included in figure 20 are data from reference 2 for five hydrocarbon fuels and comparable combustion efficiencies of isooctane obtained from interpolation of data from reference 1. Data of reference 1 were obtained in a turbojet combustor of the same design, operated with varying concentrations of oxygen in the inlet oxygen-nitrogen mixture. The values of maximum burning velocity for isooctane in various oxygen-nitrogen mixtures were obtained from reference 9.

Deviation of the isooctane data of the present investigation from the corresponding data from reference 1 might be attributed to the differences in fuel atomization resulting from the use of different fuel nozzles. There is reasonable agreement between the two sets of data and there is a definite trend toward an increase in combustion efficiency with increase in maximum burning velocity.

The data points for carbon disulfide and methanol deviate appreciably from the mean curve of figure 20. Examination of the data of table I indicates that the minimum spark-ignition energy of carbon disulfide and the latent heat of vaporization of methanol differ appreciably from

the average. No consistent trend in the relative position of the data points of figure 20 with the relative value of minimum spark-ignition energy is evident. However, the data of figure 20 generally indicate that for fuels with approximately the same maximum burning velocity, those fuels with higher latent heats of vaporization give lower combustion efficiency. Accordingly, an attempt was made to correlate combustion efficiency in terms of both maximum burning velocity and latent heat of vaporization. The correlation obtained is shown in figure 21 where combustion efficiency is plotted against the parameter $u_x/L_v^{1/3}$. Here u_x is the maximum burning velocity (cm/sec) at atmospheric pressure and temperature and L_v is the latent heat of vaporization (Btu/lb of air) at the normal boiling point. Interpolated data from figure 19 are included for butylsilane, acrylonitrile, and acrolein at two inlet-air mass-flow rates and air temperature conditions, and for carbon disulfide at one inlet-air mass-flow rate and two inlet-air temperatures. The combustion efficiency data of reference 2 for isooctane, cyclohexane, methylcyclohexane, *n*-heptane, and benzene are also included in the correlation.

A reasonable correlation of the combustion efficiency data is obtained for the majority of the fuels and operating conditions. However, the parameter $u_x/L_v^{1/3}$ must be regarded as tentative in view of the serious deviation of some fuels from the mean correlation curve at some test conditions.

A comparison of the correlation data of figure 21 with those of figure 20 shows that the modified correlating parameter $u_x/L_v^{1/3}$ (1) improved the correlation of methanol, acrylonitrile, and acetone data; (2) did not improve the correlation of carbon disulfide data; and (3) increased the deviations of 2-pentene and acrolein data. The deviations exhibited by both correlations (u_x and $u_x/L_v^{1/3}$) might be attributed to a number of different factors. The values of u_x were determined at conditions considerably different from those used in the turbojet-combustor tests; the effects of variables such as air temperature and pressure and fuel-air contact time on flame speed varied considerably among the fuels tested. Furthermore, a number of variables that influence the primary-zone mixture conditions were not considered; for example, the effects of physical properties of the fuel on fuel atomization and on spray penetration in the combustor primary zone.

Data presented in reference 10 suggest that the rate-controlling process in the turbojet combustor changes with combustor operating conditions. Similarly, the rate-controlling process might be expected to change with fuel properties; for example, the combustion rate of a low-flame-speed fuel might be limited by its flame speed, whereas the

combustion rate of a high-flame-speed fuel might be limited by its vaporization characteristics. If this is true, considerably more data than are presented herein will be required to establish an adequate correlation between combustion performance and fuel properties.

Maximum Temperature Rise

Comparisons of several physical properties (boiling point, latent heat of vaporization, and heat content at the spontaneous ignition temperature) and fundamental combustion properties (flammability range and spontaneous ignition temperature) with the maximum temperature-rise data of the fuels, presented in figures 5 to 17, indicated that none would satisfactorily predict the relative performance trends obtained.

In figure 22 the maximum combustor temperature rise is plotted against maximum burning velocity at each of the combustor inlet-air conditions investigated. Data are presented only for those fuels for which maximum temperature-rise points were obtained at all combustor inlet-air conditions. Maximum temperature-rise data from reference 2 are included in the figure. With the exception of acetone and 2-pentene, the data indicate a slight trend toward an increase in maximum temperature rise with increase in maximum burning velocity. This trend, which is substantiated somewhat by the limited maximum temperature-rise data obtained with acrolein, acrylonitrile, and propylene oxide, is consistent with the trend reported in reference 2. However, again the scatter of the data is too great to permit a prediction of maximum temperature rise in terms of maximum burning velocity. No consistent trend in the relative position of the data points in figure 22 with the relative value of latent heat of vaporization was found. Accordingly, the parameter $u_x/L_v^{1/3}$ would not provide a satisfactory correlation of the data of figure 22.

CONCLUDING REMARKS

Results of this investigation indicated, in general, that fuels with higher values of maximum burning velocities attained higher combustion efficiency and maximum temperature rise. An approximate correlation of combustion efficiency at a constant heat-input value with maximum burning velocity and latent heat of vaporization was obtained in this investigation; however, serious deviations from the correlation were observed for some fuels at some of the test conditions. These deviations may be attributed to (1) the effects of fuel atomization and primary mixture distribution on combustor performance, or (2) insufficient knowledge of the fundamental combustion characteristics of the fuels at the combustion operating conditions investigated.

The results of this investigation suggest that no single fuel property or combination of fuel properties will adequately correlate the effect of changes in fuel type on combustor performance over the entire engine-operating range. Both physical and fundamental combustion properties are probably important factors in combustor performance.

SUMMARY OF RESULTS

In order to determine a possible relation among the physical or fundamental combustion properties of fuels, or both, and their combustion performance, investigations of 13 pure fuels were conducted in a single tubular combustor. The following results were obtained.

1. The data indicated an approximate trend toward an increase in combustion efficiency and maximum temperature rise across the combustor with increase in maximum burning velocity.
2. At a heat-input value of 250 Btu per pound of air, a tentative correlation was obtained between combustion efficiency and the parameter $u_x/L_v^{1/3}$, where u_x is the maximum burning velocity at atmospheric pressure and temperature and L_v is the latent heat of vaporization at the normal boiling point.
3. On the basis of combustion efficiency at a heat-input value of 250 Btu per pound of air, the general performance order of the fuels was butylsilane, carbon disulfide, and propylene oxide highest; acrolein, acrylonitrile, 2-pentene, diethyl ether, n-pentane, isooctane, and acetone intermediate; isopentane, 2,2-dimethylbutane, and methanol lowest.
4. Changing inlet-air mass flow and inlet-air temperature altered the sensitivity of combustor performance to changes in fuel type. Increases in air mass-flow rate or decrease in inlet-air temperature generally decreased combustor performance and increased differences in combustor performance among fuels.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, February 4, 1955

REFERENCES

1. Graves, Charles C.: Effect of Oxygen Concentration of the Inlet Oxygen-Nitrogen Mixture on the Combustion Efficiency of a Single J33 Turbojet Combustor. NACA RM E52F13, 1952.
2. Wear, Jerrold D., and Dittrich, Ralph T.: Performance of Pure Fuels in a Single J33 Combustor. I - Five Liquid Hydrocarbon Fuels. NACA RM E52J03, 1952.
3. Turner, L. Richard, and Bogart, Donald: Constant-Pressure Combustion Charts Including Effects of Diluent Additions. NACA Rep. 937, 1949. (Supersedes NACA TN's 1086 and 1655.)
4. Huff, Vearl N., Gordon, Sanford, and Morrell, Virginia E.: General Method and Thermodynamic Tables for Computation of Equilibrium Composition and Temperature of Chemical Reactions. NACA Rep. 1037, 1951. (Supersedes NACA TN's 2113 and 2161.)
5. Ribaud, M. G.: Constantes Thermodynamiques des Gaz aux Températures Élevées. No. 266, Pub. Sci. et Tech. (Paris), 1952.
6. Southard, J. C.: A Modified Calorimeter for High Temperatures. The Heat Constant of Silica, Wollastonite and Thorium Dioxide above 25°. Jour. Am. Chem. Soc., vol. 63, 1941, pp. 3142-3146.
7. Metzler, Allen J.: Minimum Ignition Energies of Six Pure Hydrocarbon Fuels of the C₂ and C₆ Series. NACA RM E52F27, 1952.
8. Metzler, Allen J.: Minimum Spark-Ignition Energies of 12 Pure Fuels at Atmospheric and Reduced Pressure. NACA RM E53H21, 1953.
9. Dugger, Gordon L., and Graab, Dorothy D.: Flame Speeds of 2,2,4-Trimethylpentane-Oxygen-Nitrogen Mixtures. NACA TN 2680, 1952.
10. Childs, J. Howard, and Graves, Charles C.: Relation of Turbine-Engine Combustion Efficiency to Second-Order Reactions Kinetics and Fundamental Flame Speed. NACA RM E54G23, 1954.
11. Rossini, Frederick D., et al.: Selected Values of Properties of Hydrocarbons. Circular C461, Nat. Bur. Standards, Nov. 1947.
12. Jackson, Joseph L.: Spontaneous Ignition Temperatures of Pure Hydrocarbons and Commercial Fluids. NACA RM E50J10, 1950. (See also Ind. and Eng. Chem., vol. 43, no. 12, Dec. 1951, pp. 2869-2870.)

13. Doss, M. P.: Physical Constants of the Principal Hydrocarbons. Third ed., The Texas Co., 1942.
14. Simon, Dorothy Martin: Flame Propagation - Active Particle Diffusion Theory. Ind. and Eng. Chem., vol. 43, no. 12, Dec. 1951, pp. 2718-2721.
15. Maxwell, J. B.: Data Book on Hydrocarbons. Second Printing, D. Van Nostrand Co., Inc., 1951.
16. Reynolds, Thaine W.: Effect of Fuels on Combustion Efficiency of 5-Inch Ram-Jet Type Combustor. NACA RM E53C20, 1953.
17. Anon.: Survey of Bumblebee Activities. Rep. No. 113, Appl. Phys. Lab., Johns Hopkins Univ., Nov. 1949. (Contract NOrd 7386 with Bur. Ord., U.S. Navy.)
18. Anon.: International Critical Tables. Vol. I. McGraw-Hill Book Co., Inc., 1926.
19. Chemical Research Division Staff: Physical Properties and Thermodynamic Functions of Fuels, Oxidizers, and Products of Combustion. I - Fuels. Rep. R-127, Battelle Memorial Inst., The Rand Corp., Jan. 1949. (USAF Contract W33-038-ac-14105, Proj. RAND.)
20. Kharasch, M. S.: Heats of Combustion of Organic Compounds. Res. Paper 41, Bur. Standards Jour. Res., vol. 2, no. 1, Jan. 1929, pp. 359-430.
21. Calcote, H. F., et al.: Minimum Spark Ignition Energy Correlation with Ramjet and Turbojet Burner Performance. TP-36, Experiment, Inc., Richmond (Va.), Mar. 1950. (Final Rep. No. 1 to Bur. Aero. under Contract NOa(s) 10115.)
22. Perry, John H., ed.: Chemical Engineers' Handbook. Third ed., McGraw-Hill Book Co., Inc., 1950.
23. Anon.: Chemical Safety Data Sheets SD-12, SD-29, and SD-31. Manufacturing Chemists' Assoc., Inc., Washington (D.C.), June 1953.
24. Tannenbaum, Stanley, Kaye, Samuel, and Lewenz, George F.: Synthesis and Properties of Some Alkylsilanes. Jour. Am. Chem. Soc., vol. 75, no. 15, Aug. 5, 1953, pp. 3753-3757.
25. Anon.: Acrolein. Rep. No. S-9941, Shell Dev. Co., Jan. 6, 1947.
26. Scott, G. S., Jones, G. W., and Scott, F. E.: Determination of Ignition Temperatures of Combustible Liquids and Gases. Anal. Chem., vol. 20, no. 3, Mar. 1948, pp. 238-241.

27. Hodgman, Charles, D., ed.: Handbook of Chemistry and Physics.
Thirty-third ed., Chem. Rubber Pub. Co., 1951-1952.

TABLE I. - LABORATORY INSPECTION DATA AND PHYSICAL AND FUNDAMENTAL COMBUSTION DATA OF FUELS

Fuel	Physical data															Fundamental combustion data				
	Laboratory values						Literature values for pure fuel									Lower heat of combustion, Btu/lb	Minimum ignition energy, joules	Spontaneous ignition temperature, °F	Flammability range, percent stoichiometric (rich minus lean)	Maximum burning velocity, cm/sec
	Density at 68° F	Refractive index at 68° F	Freezing point, °F	Hydrogen-carbon weight ratio	Lower heat of combustion, Btu/lb	Estimated purity, mole percent	Density at 68° F	Refractive index at 68° F	Freezing point, °F	Normal boiling point, °F	Latent heat of vaporization at normal boiling point, Btu/lb	Heat content 77° F through spontaneous ignition temperature, Btu/lb	Viscosity at 68° F, centipoises	Hydrogen-carbon weight ratio	Heat content 77° F through normal boiling point, Btu/lb					
																(a)	(b)			
Isooctane	0.692	^c 1.3915	^c -161.3	^c 0.189	^c 19,065	^c 99.6	^d 0.692	^d 1.3915	^d -161.3	^d 210.6	^d 116.7	^d 603	^e 0.503	0.189	^d 75	^d 19,065	3.0x10 ⁻³	837	^f 307	^g 34.6
n-Pentane	.627	1.3580	-201.5	.201	19,340	95.6	^d .626	^d 1.3575	^d -201.5	^d 96.9	^d 153.6	^d 409	^e .232	.201	^d 12	^d 19,340	2.2	544	^f 305	^g 38.5
Isopentane	.620	1.3538	-257.0	.201	19,305	95.0	^d .620	^d 1.3537	^d -255.8	^d 82.1	^d 145.7	^d 583	^e .223	.201	^d 3	^d 19,303	2.4	800	^f 309	^g 36.6
2,2-Dimethylbutane	.653	1.3702	-187.8	.195	19,146	95.0	^d .649	^d 1.3688	^d -147.5	^d 121.5	^d 131.2	^d 593	^e .375	.195	^d 25	^d 19,161	2.7	824	^f 296	^g 35.7
2-Pentene	.651	1.3798	Glassy	.185	19,058	93.0	^d .658	^d 1.3810	^d -230.5	^d 98.2	^h 155.0	---	---	.185	^d 11	^d 19,040	2.2	---	^f 370	ⁱ 43.9
Methanol	.793	1.3286	-144.6	----	8,370	99.1	^j .792	^k 1.3290	^l -144.0	^l 148.1	^l 474.0	---	^m .581	----	^m 25	ⁿ 8,580	2.0	878	^f 245	ⁱ 51.1
Propylene oxide	.830	1.3660	-169.4	----	12,994	99.0	^o .839	----	----	^o 95.0	^h 234.0	---	^o .380	----	^p 10	ⁿ 12,994	1.6	532	^q 402	^f 67.2
Diethyl ether	.715	1.3522	-190.0	----	14,550	99.3	^o .714	^k 1.3520	^l -177.3	^l 94.1	^l 151.0	^m 173	^m .269	----	^m 10	ⁿ 14,550	2.5	379	^q 1028	ⁱ 40.1
Carbon disulfide	----	----	----	----	5,830	99+	^o 1.263	^k 1.6290	^o -163.5	^j 115.0	^m 148.0	^m 261	^m .376	----	^m 11	ⁿ 5,830	.33	248	^q 748	ⁱ 52.5
Acetone	.791	1.3585	-139.8	----	12,094	98.0	^l .792	^r 1.3589	^l -138.3	^l 133.0	^q 224.1	^m 868	^m .320	----	^m 37	ⁿ 12,241	2.55	1042	^q 206	^h 42.3
Butylsilane	.689	1.3914	-216.8	----	18,366	----	^s .679	^s 1.3922	^s -216.8	^s 133.6	^s 147.1	---	----	----	^p 40	^s 18,366	.66	----	---	^f 120.0
Acrylonitrile	.807	----	----	----	13,740	----	^j .823	^t 1.3914	^t -118.4	^j 171.0	^t 264.6	^t 677	----	----	^t 84	^t 13,740	1.6	^j 898	^q 514	^f 47.0
Acrolein	.871	----	----	----	11,888	----	^u .839	^u 1.4017	^u -124.5	^u 126.8	^u 221.4	---	----	----	^p 30	ⁿ 11,888	1.4	^v 532	---	ⁱ 60.3

^a Refs. 7 and 8.^b Ref. 12 except as noted.^c Pure fuel value.^d Ref. 11.^e Ref. 13.^f Calculated data.^g Ref. 14.^h Ref. 16.ⁱ Data from ref. 17 corrected by a factor from ref. 14.^j Ref. 23.^k Ref. 18.^l Ref. 15.^m Ref. 19.ⁿ Ref. 20.^o Ref. 21.^p Interpolated values from available data.^q Ref. 22.^r Data from ref. 27 obtained at 66.9° F.^s Ref. 24.^t Data compiled by Monsanto Chemical Co.^u Ref. 25.^v Ref. 26.

TABLE II. - PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(a) Isooctane; combustor-inlet total temperature, 660° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
1	0.595	79	26.8	0.0125	21.1	75	238.5	1460	800	87.2	
2	.595		31.6	.0148	21.9	73	281.2	1610	955	89.6	
3	.595		37.0	.0173	24.2	73	329.3	1740	1080	87.8	
4	.598		41.7	.0194	24.4	74	369.3	1860	1201	88.1	
5	.600		45.0	.0209	24.9	67	397.1	1925	1265	87.0	
6	.600		21.6	.0100	20.4	73	190.6	1275	615	82.4	
7	.599		46.3	.0215	25.1	67	409.3	1960	1300	87.0	
8	.601		47.5	.0220	--	--	418.5	1965	1305	85.6	Blow-out (Av. of 2 pts.)
9	.800	105	19.0	.0066	19.9	72	125.8	960	301	59.7	
10	.800		24.7	.0086	20.9	71	163.5	1115	456	70.4	Inlet-air velocity unsteady
11	.800		30.5	.0106	21.4	68	201.9	1280	620	78.6	
12	.796		36.5	.0127	24.4	67	242.9	1420	760	81.2	Orifice pressure unsteady
13	.800		41.7	.0145	24.8	66	276.1	1520	860	81.7	
14	.802		48.0	.0166	25.1	65	317.1	1665	1005	84.3	
15	.803		52.5	.0182	25.4	--	346.2	1750	1090	84.5	
16	.804		56.5	.0195	25.5	64	372.1	1830	1173	85.3	
17	.800		59.7	.0207	26.5	60	395.2	1870	1208	83.2	Resonance
18	.802		63.5	.0220	26.2	60	419.4	1900	1240	80.1	Resonance
19	.803		72.5	.0251	----	61	478.2	1960	1299	75.2	Blow-out resonance
20	.803		66.5	.0230	25.4	--	438.5	1915	1260	78.8	Blow-out resonance
21	.803		33.8	.0117	23.3	63	222.9	1365	706	81.7	
22	.600	79	39.0	.0181	18.9	62	344.3	1785	1124	87.8	
23	.977	132	19.3	.0055	19.9	65	104.6	895	238	56.4	
24	.977		26.4	.0075	20.7	65	143.1	985	328	57.3	
25	.977		31.2	.0089	21.5	61	169.1	1085	428	63.8	
26	.977		39.5	.0112	24.0	61	214.1	1250	592	70.8	
27	.977		47.0	.0134	24.6	63	254.7	1365	706	71.8	
28	1.000		56.5	.0157	24.7	--	299.1	1470	812	71.2	
29	1.000		20.4	.0057	19.1	72	108.0	900	240	55.1	
30	1.000		83.1	.0231	----	61	440.0	1610	952	58.3	Blow-out
31	1.000		63.5	.0176	25.8	59	336.3	1570	911	71.8	
32	1.003		51.0	.0141	25.1	62	269.2	1390	731	70.6	
33	1.004		74.4	.0206	26.8	58	392.5	1615	956	65.3	
34	1.299	173	30.7	.0066	21.1	67	125.2	870	213	42.3	
35	1.299		19.0	.0040	18.8	71	77.48	830	172	54.7	
36	1.305		41.1	.0087	73.3	64	166.8	945	286	43.0	
37	1.306		51.1	.0109	19.5	61	207.3	1010	352	43.0	
38	1.303		61.1	.0130	19.8	58	248.3	1080	423	43.5	
39	1.305		71.0	.0151	25.9	58	288.1	1115	456	40.7	
40	1.295		80.5	.0173	31.0	56	329.3	1140	482	37.9	Exhaust pressure unsteady
41	1.294		85.7	.0184	----	--	350.9	1155	497	36.8	Blow-out
42	1.297		63.5	.0136	24.8	58	259.3	1085	426	42.0	
43	.996	132	45.3	.0126	24.7	61	240.8	1330	669	71.7	
44	.998		45.0	.0125	24.4	62	258.7	1320	661	71.4	
45	.800	105	44.4	.0154	24.2	63	294.0	1605	942	84.7	
46	.600	79	37.5	.0174	24.8	65	331.0	1755	1096	88.7	
47	1.025	132	22.9	.0062	21.8	74	118.3	1145	285	59.9	Inlet pressure unsteady
48	1.025		53.6	.0145	27.6	--	277.0	1390	730	68.6	Inlet pressure unsteady
49	1.025		77.1	.0209	31.0	--	398.3	1535	874	58.6	Inlet pressure unsteady
50	1.330	173	27.1	.0057	21.0	71	107.9	870	210	48.3	Inlet pressure unsteady
51	1.330		53.6	.0112	27.3	--	213.3	1000	341	40.5	Inlet pressure unsteady
52	1.330		77.5	.0162	30.6	66	308.7	1050	391	32.6	Inlet pressure unsteady
53	1.003	132	56.3	.0156	27.1	69	297.2	1450	789	69.6	
54	1.003		77.1	.0214	31.0	--	407.0	1595	934	61.6	
55	.800	105	21.9	.0076	22.3	--	145.0	1055	392	67.9	
56	.800		46.7	.0162	25.4	70	309.2	1645	983	84.4	
57	.800		64.1	.0223	27.9	--	424.4	1880	1221	78.7	
58	.600	79	23.6	.0109	21.7	74	208.4	1355	694	85.7	
59	.600		43.3	.0201	24.6	72	382.3	1890	1229	87.4	
60	1.300	173	61.3	.0131	26.6	68	249.8	1060	400	40.8	

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs.]

(a) Concluded. Isooctane; combustor-inlet total temperature, 660° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
61	1.300	173	81.1	0.0173	32.9	67	330.4	1095	435	34.1	
62	.598	79	30.4	.0141	21.7	72	269.2	1580	916	89.5	
63	.598	↓	43.7	.0203	23.9	72	387.0	1900	1240	87.5	
64	1.302	173	26.6	.0057	19.8	72	108.2	875	214	49.0	
65	1.298	↓	79.2	.0170	30.8	71	323.2	1135	476	38.1	
66	1.302	↓	35.7	.0076	25.7	81	145.22	925	264	45.4	
67	1.302	↓	56.6	.0121	26.4	81	230.31	1055	395	43.6	
68	1.302	↓	78.3	.0167	30.7	81	318.58	1125	465	37.7	
69	.802	105	46.5	.0161	26.5	81	307.14	1625	965	83.3	
70	.802	↓	69.1	.0240	28.4	81	456.23	1940	1280	77.3	
71	.596	79	38.8	.0181	25.1	82	344.70	1790	1130	88.2	
72	.596	↓	44.4	.0207	27.2	82	394.45	1910	1249	86.4	
73	.996	132	54.3	.0151	27.1	--	288.64	1435	775	70.2	
74	.996	↓	54.3	.0151	24.4	--	288.64	1455	795	72.1	
75	.602	79	28.2	.0130	26.9	70	248.04	1505	842	88.6	
76	.602	↓	43.3	.0200	29.3	69	380.92	1890	1227	87.6	
77	1.300	173	22.5	.0049	22.4	72	91.66	865	205	55.3	
78	1.305	↓	48.5	.0099	25.3	71	188.7	970	325	43.4	Inlet pressure unsteady
79	.995	132	35.5	.0099	21.7	72	189.0	1145	510	68.5	
80	.995	↓	59.1	.0165	27.6	72	314.6	1495	835	69.9	
81	.599	79	21.3	.0099	24.4	77	188.3	1280	619	84.0	
82	.599	↓	28.8	.0134	25.8	78	254.7	1535	873	89.7	
83	.599	↓	35.0	.0162	27.4	77	309.4	1685	1023	88.0	
84	.599	↓	40.4	.0187	23.4	77	357.3	2030	1169	88.4	
85	.803	105	39.9	.0138	23.2	77	263.1	1505	845	84.0	
86	.803	↓	55.9	.0193	28.4	76	368.7	1795	1136	83.2	
87	.803	↓	68.0	.0235	28.9	76	448.4	1920	1260	77.3	
88	.599	79	21.8	.0101	19.2	78	192.7	1295	632	83.9	
89	.599	↓	40.9	.0190	24.9	77	361.7	1625	1166	87.1	
90	.599	↓	47.5	.0220	---	77	420.0	1965	1305	85.3	Blow-out
91	.592	↓	21.6	.0101	19.9	80	193.3	1205	545	71.8	
92	.592	↓	34.3	.0161	26.2	80	306.9	1675	1016	88.0	
93	.592	↓	42.2	.0198	27.5	80	377.5	1870	1212	87.1	
94	.592	↓	48.5	.0228	---	80	433.9	2005	1347	85.6	Blow-out
95	.592	↓	24.0	.0113	24.1	85	214.7	1375	718	86.2	
96	.800	105	21.2	.0074	22.3	85	140.3	1015	355	63.3	
97	.800	↓	48.7	.0169	26.4	85	322.4	1660	1000	82.5	
98	.800	↓	67.0	.0233	28.6	85	443.5	1910	1250	77.4	
99	.800	↓	72.4	.0251	---	84	479.3	1950	1290	74.4	Blow-out
100	1.000	132	78.4	.0218	34.5	82	415.2	1585	925	59.8	Inlet pressure unsteady
101	1.000	↓	80.1	.0223	---	82	424.2	1565	905	57.3	Inlet pressure unsteady, Blow-out
102	.600	79	25.5	.0118	22.3	87	225.2	1420	758	87.1	
103	.600	↓	34.5	.0160	26.4	87	304.5	1685	1024	89.4	
104	.600	↓	40.5	.0188	27.5	87	357.5	1835	1173	88.7	
105	.600	↓	47.3	.0219	---	87	417.5	1970	1309	86.1	Blow-out resonance
106	.800	105	27.0	.0094	21.8	86	178.7	1175	515	73.1	
107	.800	↓	51.5	.0179	27.2	86	340.9	1725	1065	83.7	
108	.800	↓	66.2	.0230	26.9	86	438.3	1925	1265	79.3	
109	.800	↓	72.2	.0251	---	86	478.0	1950	1290	74.6	Blow-out
110	1.000	132	29.2	.0081	22.9	88	154.6	1045	384	62.4	
111	1.000	↓	75.8	.0211	32.3	88	401.5	1585	925	61.7	
112	.998	↓	82.4	.0229	---	88	437.2	1600	939	57.9	Blow-out
113	1.300	173	32.8	.0070	25.4	90	133.6	900	241	45.0	
114	.823	105	34.8	.0012	23.3	88	223.82	1370	706	81.4	Inlet pressure unsteady
115	.823	↓	56.5	.0191	29.7	88	363.57	1795	1135	84.2	Inlet pressure unsteady
116	.998	132	54.6	.0152	19.0	89	289.79	1460	798	72.1	Inlet temperature unsteady
117	.998	↓	69.1	.0192	29.8	88	366.62	1630	984	71.6	Inlet pressure unsteady

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(b) Isooctane; combustor-inlet total temperature, 500° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input, Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
118	1.297	130	31.0	0.0066	21.3	64	126.6	680	179	34.4	
119	1.297		40.0	.0086	----	61	163.4	735	234	35.1	
120	1.297		50.8	.0109	24.7	59	207.5	810	308	36.6	
121	1.297		60.0	.0129	25.2	58	245.0	870	369	37.4	
122	1.297		69.5	.0149	26.2	57	283.9	925	424	37.3	
123	1.297	100	79.5	.0170	31.1	55	324.7	985	482	37.4	
124	1.297		87.6	.0188	38.7	55	357.7	1015	514	36.4	
125	1.296		93.3	.0200	----	56	381.4	1020	519	34.6	Blow-out
126	1.000		30.0	.0063	21.5	63	158.9	805	304	47.0	Inlet pressure unsteady
127	.999		41.6	.0116	19.8	62	220.6	1005	505	57.1	
128	.998	80	52.3	.0146	25.4	59	277.6	1185	685	62.6	
129	.998		70.0	.0195	----	57	371.5	1410	909	63.6	
130	.800		43.8	.0152	24.9	58	290.0	1370	870	77.0	
131	.801		47.2	.0164	25.4	58	312.2	1470	970	80.5	Resonance
132	.800		49.1	.0171	25.6	57	325.1	1515	1015	81.3	Resonance
133	.799	100	54.0	.0188	25.8	56	358.1	1605	1104	81.0	
134	1.000		35.5	.0099	24.2	60	188.0	910	409	53.8	
135	1.000		48.7	.0135	25.4	58	258.0	1115	614	60.0	
136	1.000		45.7	.0127	----	58	242.0	1070	569	59.0	
137	.796		28.0	.0098	21.4	65	186.3	935	436	57.9	
138	.796	80	24.7	.0086	21.3	65	164.3	855	356	53.3	
139	.796		44.5	.0155	----	61	296.1	1380	881	76.5	Resonance
140	.796		46.8	.0163	25.1	60	311.4	1470	970	80.7	Resonance
141	.796		49.6	.0173	25.4	59	330.1	1535	1035	81.8	Resonance
142	.796		52.6	.0184	25.6	59	349.9	1580	1080	81.0	Resonance
143	.796	60	59.5	.0208	----	59	395.9	1665	1165	78.0	Resonance
144	.796		66.5	.0232	----	58	443.2	1740	1239	74.9	Resonance
145	.800		58.4	.0203	----	58	386.7	1635	1135	77.6	Resonance
146	.800		69.6	.0242	----	57	460.9	1760	1260	73.5	Resonance
147	.796		56.6	.0198	25.7	63	376.6	1625	1125	78.8	Resonance
148	.792	80	58.9	.0207	25.8	63	394.0	1660	1160	78.0	Resonance
149	.793		62.6	.0219	26.1	63	418.2	1710	1210	77.1	Resonance
150	.802		61.5	.0213	25.8	63	406.2	1695	1195	78.2	
151	.802		57.3	.0199	25.4	63	378.5	1645	1145	79.9	
152	.607		61.5	.0213	25.7	63	406.2	1685	1185	77.5	
153	.798	60	34.6	.0158	23.9	66	302.1	1510	1010	86.8	
154	.798		45.2	.0157	24.8	68	300.0	1360	859	73.6	
155	.799		41.1	.0143	24.8	68	272.5	1270	769	71.9	
156	.800		38.2	.0133	24.8	68	252.9	1205	705	70.6	
157	.802		34.3	.0119	24.0	69	226.5	1110	609	67.5	
158	.799	60	32.4	.0113	22.9	69	214.7	1075	574	66.9	
159	.801		30.1	.0104	22.1	70	199.1	1020	519	64.9	
160	.806		27.1	.0093	21.4	71	178.1	925	424	58.9	
161	.802		22.8	.0079	20.8	71	150.6	815	314	51.1	
162	.800		49.0	.0170	25.1	68	324.4	1495	994	76.7	
163	.799	60	55.1	.0192	25.3	68	365.4	1610	1109	79.9	
164	.798		58.5	.0204	25.9	67	388.2	1655	1154	78.7	
165	.798		64.2	.0223	26.3	67	426.0	1720	1219	76.4	
166	.799		72.4	.0252	26.3	--	480.0	1730	1229	68.8	Blow-out
167	.597		27.7	.0219	21.7	71	245.8	1280	780	80.6	
168	.597	60	24.1	.0112	21.6	72	213.8	1155	655	77.0	
169	.597		20.5	.0095	21.3	73	181.9	1010	510	69.7	
170	.598		30.1	.0140	22.2	73	266.6	1370	870	83.6	
171	.598		33.3	.0155	23.4	72	295.0	1465	966	84.7	Resonance
172	.598		36.0	.0167	24.6	72	318.8	1465	1066	87.2	
173	.595	100	38.0	.0177	23.9	72	338.3	1610	1120	86.9	
174	.597		41.1	.0191	----	72	364.6	1685	1185	85.9	Resonance blow-out
175	.998		27.1	.0075	21.3	66	143.8	755	255	43.4	
176	1.000		28.9	.0080	21.8	66	153.1	790	289	46.3	
177	1.000		33.2	.0092	23.2	65	175.9	865	364	51.0	

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(b) Continued. Isooctane; combustor-inlet total temperature, 500° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input, Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
178	1.000	100	38.5	0.0107	24.5	65	203.8	950	449	54.7	
179	.998		44.6	.0124	25.0	63	236.6	1050	549	58.1	
180	.998		46.7	.0130	24.8	63	247.9	1090	589	59.7	
181	1.002		49.6	.0138	25.0	62	262.2	1140	639	61.5	
182	1.000		56.5	.0157	25.4	61	299.2	1235	734	62.5	
183	1.000		59.2	.0164	25.9	61	313.5	1260	759	61.9	
184	.997		67.5	.0188	26.7	59	357.9	1380	880	63.7	
185	.594	60	29.8	.0139	21.9	64	265.8	1355	855	82.3	
186	.598		25.2	.0117	21.3	68	223.1	1190	690	78.0	
187	.601		19.0	.0088	21.0	69	167.4	930	430	63.5	
188	1.004	100	59.2	.0164	25.9	62	312.4	1275	775	63.5	
189	1.004		62.6	.0173	26.0	60	330.3	1325	824	64.2	
190	1.004		64.2	.0178	26.1	60	338.7	1335	834	63.5	
191	1.004		67.5	.0187	26.4	60	356.2	1375	875	63.6	
192	.997		47.6	.0133	25.6	65	252.9	1100	600	59.7	
193	.998		53.5	.0149	25.8	64	283.9	1200	701	62.7	
194	.998		62.0	.0173	26.2	63	329.1	1310	809	63.2	
195	1.000		69.1	.0192	26.9	63	365.9	1390	890	63.1	
196	1.002		71.6	.0199	27.5	62	378.5	1410	909	62.5	
197	1.000		76.0	.0211	29.1	62	402.5	1445	944	61.3	
198	1.000		82.5	.0229	34.2	62	437.1	1460	959	57.7	
199	1.000		87.3	.0243	----	65	462.4	1410	909	51.7	
200	1.301	130	43.3	.0092	24.9	66	176.3	760	259	36.0	
201	1.301		51.1	.0109	25.0	66	208.0	830	329	39.1	
202	1.301		58.1	.0124	25.0	65	236.5	865	364	38.2	
203	1.301		66.2	.0141	26.0	64	269.4	920	419	38.8	
204	1.301		70.6	.0151	26.4	62	287.4	945	445	38.8	
205	1.301		78.5	.0168	29.9	63	319.6	990	490	38.6	
206	1.301		86.1	.0184	36.9	63	350.5	1010	510	36.8	
207	1.301		94.1	.0201	----	64	383.1	1020	520	34.5	Blow-out
208	1.300		36.8	.0079	23.4	68	149.9	710	210	34.2	
209	1.300		30.0	.0064	----	68	122.2	670	170	33.8	
210	1.300		46.5	.0099	----	68	189.4	790	290	37.7	
211	.800	80	44.6	.0155	----	69	295.3	1365	865	75.3	Inlet pressure unsteady
212	.800		46.5	.0162	25.0	69	307.9	1445	945	79.4	Inlet pressure unsteady
213	.800		41.7	.0145	25.2	69	276.1	1305	805	74.5	Inlet pressure unsteady
214	.800		41.2	.0143	25.2	70	272.8	1285	785	73.4	Inlet pressure unsteady
215	.597	60	27.6	.0128	21.3	72	244.8	1270	771	80.0	
216	.600		22.5	.0104	20.8	74	198.7	1080	580	72.9	
217	.600		32.5	.0151	22.6	73	286.9	1435	935	84.0	Resonance
218	1.000	100	41.2	.0014	24.9	71	218.1	995	494	56.4	
219	1.000		67.0	.0186	28.4	67	354.8	1360	859	62.6	Inlet pressure unsteady
220	1.000		30.6	.0085	18.8	67	162.1	815	313	47.4	
221	1.300	130	35.5	.0072	21.5	67	136.5	705	203	36.3	
222	1.000	100	30.2	.0084	22.4	74	159.9	800	300	46.0	
223	1.000		55.5	.0154	25.1	74	294.0	1220	718	62.2	
224	1.000		78.5	.0218	31.8	74	415.8	1410	908	57.1	
225	.602	60	27.3	.0126	25.7	74	240.2	1250	750	79.1	
226	.602		38.5	.0177	25.0	74	338.8	1550	1050	81.0	
227	1.302	130	36.0	.0077	26.9	77	146.4	720	219	36.5	
228	1.302		74.9	.0160	28.5	74	304.7	975	474	39.1	
229	1.302		90.3	.0193	42.9	74	367.4	995	495	34.1	
230	.799	80	38.8	.0135	26.9	74	257.2	1235	735	72.5	
231	.799		56.2	.0195	28.1	74	372.5	1605	1105	78.1	
232	.598	60	36.4	.0169	25.3	69	322.4	1575	1077	87.3	

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND
NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(b) Concluded. Isooctane; combustor-inlet total temperature, 500° R

Run	Air flow, lb/sec	Combustor- inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel- air ratio	Fuel- nozzle differ- ential pressure, lb/sq in.	Fuel tem- pera- ture, °F	Heat input, Btu/lb air	Mean combus- tor-out- let tem- perature, °R	Mean temper- ature rise through combustor, °F	Combus- tion effi- ciency, percent	Remarks
233	0.602	60	28.2	0.0130	20.9	83	248.0	1300	802	82.3	
234	.602	↓	36.1	.0167	27.1	83	317.6	1550	1050	86.2	
235	.602	↓	20.8	.0096	21.4	83	183.0	1015	516	70.1	
236	1.298	130	30.7	.0066	24.5	83	125.3	690	188	36.5	
237	1.298	↓	88.2	.0189	40.4	80	359.8	1020	519	36.6	
238	.602	60	23.3	.0108	26.1	69	205.0	1125	623	76.2	
239	.602	↓	31.9	.0147	27.9	71	280.6	1420	918	84.2	Resonance
240	.998	100	64.1	.0178	28.9	68	340.1	1325	824	62.4	
241	1.010	↓	81.5	.0224	39.2	65	427.3	1390	890	54.4	
242	1.315	130	83.6	.0177	41.3	65	336.7	1005	504	37.8	
243	.600	60	23.1	.0107	20.9	74	203.8	1110	610	74.9	
244	.600	↓	31.7	.0147	19.4	74	279.9	1415	915	84.1	Resonance
245	1.000	100	41.6	.0116	26.5	73	220.4	1015	514	58.2	
246	.600	60	39.8	.0184	26.3	71	351.4	1640	1141	85.5	Resonance
247	.998	100	71.6	.0199	30.9	69	380.0	1405	905	62.0	
248	.998	↓	88.9	.0247	----	70	471.7	1395	895	49.9	Blow-out
249	1.302	130	36.3	.0078	27.2	70	147.7	715	215	35.5	
250	1.300	↓	54.7	.0117	28.0	71	222.9	840	340	37.7	
251	1.300	↓	69.0	.0147	28.6	71	281.0	925	425	37.8	
252	1.300	↓	79.5	.0170	31.4	71	323.9	985	486	37.8	
253	.600	60	18.9	.0088	22.9	77	166.8	925	423	62.6	
254	.600	↓	37.9	.0176	26.0	78	334.6	1605	1105	86.6	
255	.598	100	30.2	.0140	25.1	78	267.5	1355	854	81.7	
256	.998	100	61.4	.0171	28.4	78	325.8	1295	794	62.6	
257	.998	100	78.5	.0219	32.3	78	416.6	1460	960	60.4	
258	1.000	100	87.1	.0242	----	78	461.2	1375	874	49.7	Blow-out
259	1.300	130	31.4	.0067	23.0	80	127.9	700	199	37.9	
260	1.300	↓	65.3	.0140	27.3	78	266.0	905	405	37.9	
261	.600	60	34.8	.0161	26.0	80	307.1	1500	1000	84.5	Resonance
262	1.300	130	37.8	.0081	26.0	80	154.0	720	220	34.9	
263	.998	100	82.4	.0229	39.0	80	437.2	1430	929	55.7	
264	.800	80	67.0	.0233	28.4	79	443.5	1730	1230	74.2	
265	.800	↓	70.5	.0245	----	79	466.7	1735	1235	71.1	Blow-out
266	.798	60	24.0	.0084	24.0	79	159.3	835	335	51.7	
267	.600	↓	25.2	.0117	25.9	88	222.5	1180	677	76.7	
268	.600	60	31.7	.0147	26.3	88	279.9	1405	904	83.0	Resonance
269	1.000	100	26.0	.0072	23.0	88	137.7	750	248	44.0	
270	1.000	↓	74.8	.0208	30.4	88	396.2	1415	913	60.1	
271	1.000	↓	81.3	.0226	34.8	81	430.5	1450	948	57.8	
272	1.000	↓	86.8	.0241	----	81	459.7	1360	860	49.0	Blow-out
273	.800	80	26.0	.0090	23.4	74	172.1	875	375	53.7	
274	.800	↓	54.3	.0189	26.5	74	359.4	1615	1115	81.6	
275	.800	↓	65.1	.0226	28.3	76	430.9	1730	1230	76.3	
276	.800	↓	70.4	.0244	----	76	465.9	1775	1275	73.7	Blow-out
277	.600	60	26.0	.0120	24.1	76	229.5	1215	715	78.7	
278	.605	60	33.5	.0154	26.4	76	293.2	1470	970	85.5	Resonance
279	.995	100	69.7	.0195	30.5	76	371.0	1390	890	62.3	
280	.995	↓	80.0	.0223	39.7	76	425.7	1460	960	59.2	
281	.995	↓	86.0	.0240	----	76	457.8	1400	900	51.6	Blow-out
282	1.300	130	33.9	.0072	26.6	77	138.1	710	209	36.9	
283	.600	60	21.3	.0099	21.3	82	188.0	1075	571	75.8	
284	.600	↓	27.1	.0126	25.9	83	239.3	1250	749	79.3	
285	1.300	130	51.5	.0110	25.4	84	209.7	810	306	36.0	
286	1.300	↓	86.0	.0184	45.4	81	350.4	1010	510	36.8	

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(c) n-Pentane; combustor-inlet total temperature, 660° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input, Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
287	0.998	132	22.5	0.0063	25.4	69	121.1	1005	343	70.7	
288	.998	↓	35.7	.0099	31.5	69	192.2	1155	493	65.2	
289	.998	↓	47.8	.0133	37.3	69	257.2	1325	664	66.8	
290	.998	↓	58.5	.0163	31.5	68	314.9	1445	784	65.4	
291	.998	↓	63.6	.0177	32.0	68	342.3	1485	825	63.7	
292	.998	↓	68.2	.0190	----	67	367.1	1505	845	61.1	Blow-out
293	.802	105	22.5	.0078	25.5	67	150.7	1125	463	77.4	
294	.802	↓	33.5	.0116	30.7	66	224.3	1340	680	78.1	Inlet pressure unsteady
295	.802	↓	43.8	.0152	33.5	66	293.4	1545	885	79.5	
296	.802	↓	62.5	.0217	33.4	66	418.7	1810	1150	74.8	Inlet pressure unsteady
297	.802	↓	66.5	.0230	----	66	455.4	1885	1225	75.5	Blow-out
298	1.300	173	23.3	.0050	28.0	69	96.3	915	254	65.3	
299	1.300	↓	36.0	.0077	31.4	69	148.8	955	294	49.5	
300	.597	79	22.9	.0107	27.7	71	206.2	1330	668	83.3	
301	.597	↓	27.1	.0126	29.4	71	243.9	1465	803	85.7	
302	.597	↓	33.5	.0156	31.3	70	301.5	1650	991	87.2	Resonance
303	.597	↓	41.6	.0194	33.3	67	374.4	1845	1185	85.8	
304	.597	↓	46.6	.0217	34.2	67	419.3	1970	1310	85.9	
305	.597	↓	48.6	.0226	----	67	437.5	2010	1351	85.3	Blow-out
306	1.300	173	27.4	.0059	29.4	67	113.2	920	258	56.6	
307	1.300	↓	53.8	.0115	31.1	67	222.4	1020	360	41.1	
308	1.300	↓	61.6	.0132	----	67	254.5	1060	400	40.1	Blow-out
309	1.300	↓	44.0	.0094	34.1	67	181.8	960	300	41.5	
310	1.300	↓	56.6	.0121	32.6	67	233.8	1030	370	40.2	
311	.806	105	58.7	.0202	34.0	68	391.3	1765	1103	76.3	
312	1.300	173	58.5	.0125	33.4	68	241.8	1060	402	42.4	
313	1.300	↓	30.2	.0065	30.6	68	124.8	925	267	53.3	
314	1.000	132	30.2	.0084	30.4	68	162.2	1105	445	69.2	
315	1.000	↓	53.1	.0148	34.4	68	285.3	1365	705	64.4	
316	1.000	↓	55.0	.0153	30.8	68	295.5	1395	735	65.0	
317	1.300	173	44.2	.0094	36.9	77	182.7	965	305	42.0	
318	1.300	↓	48.2	.0103	34.4	77	199.2	980	320	40.6	
319	1.300	↓	52.3	.0112	34.4	77	216.2	1005	345	40.4	
320	1.300	↓	58.5	.0125	34.4	76	241.8	1030	370	40.0	
321	1.010	132	43.5	.0120	36.0	76	231.3	1250	589	65.4	
322	1.300	173	49.0	.0105	33.9	74	202.5	985	326	40.7	
323	1.300	↓	40.0	.0086	33.1	74	165.3	945	286	43.4	
324	1.300	↓	36.1	.0077	31.9	72	149.2	935	276	46.3	
325	1.300	↓	26.3	.0056	31.2	72	108.7	910	251	57.3	
326	1.300	↓	50.0	.0107	33.4	71	206.6	995	336	41.1	
327	.802	105	42.5	.0147	34.7	71	284.7	1510	848	78.2	
328	.799	↓	51.4	.0179	33.7	69	345.6	1650	990	76.5	
329	.799	↓	59.2	.0206	32.4	71	398.0	1740	1079	73.3	
330	.799	↓	29.2	.0102	31.7	71	196.3	1270	609	79.3	
331	.998	132	54.3	.0151	32.4	71	292.2	1380	721	64.3	

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND
NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(d) n-Pentane; combustor-inlet total temperature, 500° R

Run	Air flow, lb/sec	Combustor- inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel- air ratio	Fuel- nozzle differ- ential pressure, lb/sq in.	Fuel tem- pera- ture, °F	Heat input, Btu/lb air	Mean combus- tor-out- let tem- perature, °R	Mean temper- ature rise through combustor, °F	Combus- tion effi- ciency, percent	Remarks
332	0.595	60	33.5	0.0156	23.5	68	302.5	1500	999	85.7	
333	.595		27.2	.0127	22.4	68	245.6	1275	775	80.2	
334	.595		22.5	.0105	20.7	69	203.1	1130	630	77.8	
335	.598		38.2	.0177	28.2	67	343.1	1595	1095	83.7	
336	.596		46.0	.0214	----	--	414.7	1750	1249	80.5	Blow-out
337	.596		43.8	.0204	28.4	--	394.7	1710	1209	81.5	Resonance
338	.798	80	21.8	.0076	23.8	67	146.8	880	379	63.5	
339	.798		33.1	.0115	25.6	67	222.8	1120	619	69.8	
340	.798		43.7	.0152	28.9	67	294.2	1335	834	72.7	
341	.798		51.6	.0180	29.0	66	347.4	1550	1048	79.0	Resonance
342	.798		53.6	.0187	----	66	360.9	1590	1089	79.3	Blow-out
343	1.001	100	23.3	.0065	23.8	69	125.0	795	294	57.5	
344	1.001		33.1	.0092	25.1	69	177.6	930	428	59.6	
345	1.001		44.2	.0123	28.5	69	237.1	1125	623	66.1	
346	1.001		52.2	.0145	31.1	69	280.0	1250	749	68.1	
347	1.004		75.8	.0210	----	69	405.6	1430	929	59.9	Blow-out
348	1.001	130	61.8	.0172	27.8	69	331.7	1385	883	68.8	
349	1.300		21.8	.0047	22.4	69	90.1	700	198	53.4	
350	1.300		33.5	.0072	26.4	69	138.4	755	256	45.2	
351	1.300		43.8	.0094	30.0	69	181.0	810	311	42.3	
352	1.300		54.3	.0116	30.8	69	224.3	920	421	46.6	
353	1.300		66.4	.0142	27.8	69	274.4	990	491	44.9	
354	1.300		79.4	.0170	----	66	328.2	1035	536	41.3	
355	.598	60	36.6	.0170	27.6	66	328.8	1550	1051	83.5	Blow-out

(e) Isopentane; combustor-inlet total temperature, 660° R

356	.799	105	24.7	.0086	31.6	71	165.8	1155	494	75.4	
357	.799		35.0	.0122	34.7	71	234.9	1335	674	74.1	
358	.799		47.0	.0163	36.2	71	315.4	1485	825	68.9	
359	.799		56.1	.0195	----	72	376.6	1560	900	63.8	Blow-out
360	1.300	173	23.8	.0051	32.4	73	98.2	900	237	59.8	
361	1.300		36.3	.0078	39.4	73	149.7	915	253	42.3	
362	1.300		48.5	.0104	41.9	73	200.0	955	293	37.0	
363	1.300		57.4	.0123	----	73	236.7	970	308	33.1	Blow-out
364	.599	79	22.2	.0103	34.6	74	198.8	1350	687	88.8	
365	.599		29.1	.0135	31.4	74	260.6	1535	874	87.9	
366	.599		33.9	.0157	35.0	74	303.5	1680	1018	89.2	
367	.599		43.9	.0204	----	74	393.0	1910	1249	86.7	Blow-out
368	1.306	173	28.7	.0061	30.3	74	117.8	905	245	51.7	
369	1.306		43.1	.0092	35.3	74	176.9	925	266	37.8	
370	1.306		51.8	.0110	38.4	74	212.7	955	298	35.4	
371	.800	105	29.6	.0103	32.0	74	198.5	1245	584	75.2	
372	.800		42.1	.0146	38.6	74	282.2	1445	784	72.6	
373	.800		51.5	.0179	38.0	74	345.2	1530	869	66.7	
374	.600	79	26.7	.0124	34.5	74	238.6	1460	798	87.0	
375	.600		36.8	.0170	37.5	73	329.0	1735	1072	87.3	Resonance
376	.600		40.8	.0189	37.4	72	364.7	1835	1172	87.0	Resonance
377	1.008	132	30.1	.0083	34.4	74	160.1	1075	418	65.7	
378	1.008		43.4	.0120	39.4	73	230.9	1190	531	58.9	
379	1.008		52.1	.0144	----	71	277.2	1235	576	53.6	Blow-out
380	.995		22.6	.0063	34.4	74	121.8	1000	341	69.8	
381	1.003		35.6	.0099	36.8	74	190.3	1130	472	62.9	
382	1.003		47.6	.0132	37.9	74	254.4	1220	560	56.6	
383	1.003		53.5	.0148	----	74	286.1	1230	570	51.5	Blow-out

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(f) Isopentane; combustor-inlet total temperature, 500° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input, Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
384	0.603	60	28.9	0.0133	25.1	75	256.9	1310	808	80.2	
385	.603		22.6	.0104	27.2	75	201.0	1070	567	70.5	
386	.603		33.9	.0156	30.0	74	301.4	1480	976	84.2	Resonance
387	.603		42.4	.0195	----	73	377.0	1645	1144	80.2	Blow-out
388	.603	↓	43.6	.0201	----	74	387.6	1660	1157	79.1	Blow-out
389	1.000	100	23.8	.0066	26.7	75	127.6	795	294	56.4	
390	1.000		35.3	.0098	31.1	75	189.3	880	379	49.5	
391	1.000		43.9	.0122	32.0	74	235.3	965	466	49.4	
392	1.000		57.6	.0160	----	74	308.9	1025	526	42.9	Blow-out
393	1.000	↓	50.5	.0140	31.8	74	270.8	1005	505	46.8	
394	1.300	130	23.2	.0050	24.8	75	95.7	695	197	50.0	
395	1.303		35.6	.0076	30.2	75	146.6	705	205	34.1	
396	1.303		47.9	.0102	31.3	75	197.3	745	245	30.5	
397	1.303		53.7	.0115	33.4	75	221.0	785	285	31.8	
398	1.303		58.7	.0125	----	75	241.7	790	290	29.7	Blow-out
399	1.303		53.6	.0114	33.6	76	220.7	765	265	29.6	Inlet pressure unsteady
400	1.305		42.3	.0090	28.4	76	173.8	725	223	31.4	
401	1.305		28.8	.0061	27.0	76	118.3	705	203	41.8	
402	.802	80	21.3	.0074	27.3	75	142.4	850	348	60.0	
403	.802		32.3	.0112	30.1	76	216.0	1055	553	64.0	
404	.802		40.5	.0140	32.1	76	270.8	1205	703	65.9	
405	.802		47.7	.0165	34.5	76	318.9	1250	749	60.1	
406	.601	60	36.0	.0166	30.4	72	321.2	1535	1034	83.9	
407	.601		40.3	.0186	30.7	72	359.5	1620	1119	82.0	
408	1.298	130	25.9	.0055	26.7	73	107.0	705	203	46.1	
409	1.300		40.5	.0087	31.8	73	167.1	725	224	32.8	Inlet pressure unsteady
410	1.302		62.3	.0133	----	73	256.6	805	302	29.2	Blow-out
411	.800	80	35.6	.0124	29.4	72	238.6	1125	624	65.8	
412	.800		50.6	.0176	33.4	72	339.2	1315	814	61.8	
413	.800		45.2	.0160	29.4	72	302.9	1285	784	66.3	
414	.800		56.7	.0197	----	72	380.1	1355	853	58.2	Blow-out
415	1.009	100	40.5	.0112	29.7	71	215.3	930	427	49.3	
416	1.009		29.9	.0082	25.4	71	158.9	815	313	48.4	
417	1.009		53.8	.0148	31.4	71	285.9	1045	542	47.7	
418	1.009		47.4	.0131	29.9	71	251.9	1010	510	50.7	
419	.999	↓	27.0	.0075	25.9	71	144.9	805	304	51.4	

(g) 2,2-Dimethylbutane; combustor-inlet total temperature, 660° R

420	.595	79	24.2	.0113	28.2	81	216.3	1290	629	74.7	
421	.595		33.5	.0156	29.1	80	299.4	1570	908	80.1	Slight resonance
422	.595		42.4	.0198	31.6	80	378.9	1825	1165	83.3	
423	.595		50.7	.0237	----	80	453.2	2000	1341	81.8	Blow-out
424	1.302	173	24.3	.0052	28.9	80	99.1	855	193	48.2	
425	1.302		44.9	.0096	30.1	80	183.4	895	235	32.2	
426	1.302		64.4	.0137	31.1	80	263.1	970	310	30.0	
427	1.302		67.8	.0145	----	80	277.0	975	325	29.9	Blow-out
428	.800	105	24.1	.0084	27.4	80	160.2	1080	420	66.0	
429	.800		35.5	.0123	31.5	80	236.1	1260	600	65.3	
430	.800		47.2	.0164	31.3	80	313.8	1515	855	71.8	
431	.800		64.1	.0223	----	80	426.2	1735	1075	68.5	Blow-out
432	.998	132	24.1	.0067	27.1	80	128.4	965	306	59.4	
433	.998		47.2	.0131	31.0	80	251.6	1160	501	51.0	
434	.998		62.5	.0174	31.4	81	333.1	1345	686	53.9	
435	.998		70.1	.0195	----	81	373.5	1390	731	51.7	Blow-out
436	1.296	173	35.7	.0077	31.5	81	146.5	850	188	32.1	
437	1.296		54.4	.0117	31.8	81	223.2	935	274	31.1	
438	1.296		31.4	.0067	29.4	81	128.9	845	185	35.7	
439	1.296		23.5	.0050	28.8	81	96.4	845	185	47.5	
440	1.296		65.5	.0140	----	81	268.8	965	305	29.0	Blow-out
441	1.002	132	33.6	.0093	30.2	81	178.3	1020	358	50.6	
442	1.002		53.9	.0149	30.5	82	286.0	1235	575	52.0	
443	1.002		64.3	.0178	32.1	82	341.4	1350	690	53.0	
444	1.002	↓	70.3	.0195	----	82	373.2	1370	710	50.2	Blow-out
445	.800	105	30.2	.0105	26.8	82	200.8	1180	520	65.9	
446	.803		43.0	.0149	28.8	82	284.7	1370	709	64.8	
447	.803		58.1	.0201	31.8	82	384.8	1655	994	69.4	
448	.803		64.6	.0224	----	82	427.9	1730	1068	67.7	Blow-out
449	.803	↓	54.5	.0189	31.9	82	360.9	1610	950	70.2	

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND

NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(h) 2,2-Dimethylbutane; combustor-inlet total temperature, 500° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input, Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
450	1.300	130	24.0	0.0051	21.8	81	98.2	670	168	41.5	Blow-out
451	1.300		40.4	.0086	----	81	165.3	765	263	39.0	
452	1.300		56.6	.0121	28.7	81	231.5	850	350	37.5	
453	1.300		80.4	.0172	----	81	328.9	950	449	34.3	
454	1.000	100	23.2	.0064	25.3	81	123.4	720	219	43.3	
455	1.000		39.0	.0108	25.4	81	207.4	955	453	54.2	Blow-out
456	1.000		55.5	.0154	27.4	81	295.2	1170	576	57.6	
457	1.000		73.5	.0204	----	80	391.0	1275	775	51.2	
458	.802	80	22.7	.0079	22.4	80	150.5	825	324	52.8	
459	.802		35.5	.0123	27.8	80	235.5	1120	619	66.1	
460	.802		48.0	.0166	29.3	80	318.4	1380	879	71.2	Blow-out
461	.802		63.1	.0219	----	80	418.5	1570	1069	67.5	
462	.600	60	24.0	.0111	21.8	80	212.7	1120	621	73.2	
463	.600		32.5	.0151	27.8	80	288.1	1405	907	81.0	Resonance
464	.600		41.8	.0194	27.9	80	370.5	1610	1109	78.8	Resonance
465	.600		46.5	.0215	----	80	412.2	1670	1169	75.4	Blow-out

(i) 2-Pentene; combustor-inlet total temperature, 660° R

466	1.300	173	25.0	.0053	31.0	77	101.8	925	265	64.5	Blow-out
467	1.300		37.6	.0080	32.3	76	153.1	965	305	49.9	
468	1.300		53.7	.0115	33.6	77	218.6	1040	380	44.1	
469	1.300		71.0	.0152	----	79	289.1	1105	445	39.5	
470	.600	79	22.3	.0103	27.4	80	196.7	1345	682	89.0	
471	.600		31.2	.0144	----	79	275.2	1630	969	92.9	Slight resonance
472	.600		45.9	.0213	34.0	79	405.0	1965	1304	88.2	Resonance
473	.600		54.1	.0251	----	79	477.4	2135	1474	86.2	Blow-out
474	1.000	132	24.8	.0069	30.9	80	131.3	1055	396	75.1	Blow-out
475	1.000		41.9	.0116	34.8	79	221.8	1265	606	70.0	
476	1.000		59.7	.0166	35.4	79	316.0	1440	781	64.8	
477	.800	105	27.2	.0094	31.3	82	180.0	1255	595	84.2	
478	.800		47.3	.0164	36.0	80	312.9	1620	960	81.3	
479	.800		57.6	.0200	34.8	79	381.2	1795	1135	80.5	Blow-out
480	.800		63.4	.0220	----	79	419.5	1835	1176	76.3	
481	1.000	132	53.5	.0149	34.4	80	283.2	1405	744	68.4	Blow-out
482	1.000		65.4	.0182	----	80	346.3	1490	829	63.2	

(j) 2-Pentene; combustor-inlet total temperature, 500° R

483	1.300	130	21.9	.0047	22.0	62	89.2	710	208	56.6	Blow-out
484	1.300		41.8	.0089	28.0	65	170.2	860	359	51.9	
485	1.300		55.9	.0119	27.6	65	227.6	995	494	54.1	
486	1.300		75.6	.0162	31.3	62	307.8	1120	619	50.9	
487	1.300		87.5	.0187	44.6	62	356.4	1140	639	45.7	
488	.598	60	24.0	.0112	20.4	64	212.5	1210	710	84.2	Slight resonance
489	.598		34.1	.0158	26.3	64	301.9	1525	1025	88.1	
490	.598		46.4	.0216	28.8	65	410.7	1815	1315	85.7	
491	.598		50.3	.0234	29.4	65	445.2	1865	1365	82.7	
492	1.000	100	24.2	.0067	19.5	74	128.1	805	303	57.8	
493	1.000		43.4	.0121	29.2	67	229.8	1095	594	64.8	Blow-out
494	1.000		55.7	.0155	28.9	65	294.8	1320	819	71.1	
495	1.000		74.0	.0206	30.2	65	391.8	1505	1005	67.2	
496	.998		80.6	.0224	34.9	65	427.5	1525	1023	63.0	
497	.800	80	23.2	.0081	23.3	65	153.5	870	370	59.2	
498	.800		41.5	.0144	28.9	66	274.6	1310	810	75.3	Blow-out
499	.800		58.1	.0202	30.4	65	384.4	1695	1194	82.3	
500	.800		66.0	.0229	----	65	436.8	1775	1274	78.1	
501	.800		49.1	.0171	28.8	66	324.9	1495	994	79.5	

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(k) Methanol; combustor-inlet total temperature, 660° R

Run	Air flow, lb/sec	Combustor reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input, Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
502	0.600	79	33.6	0.0156	25.2	87	130.2	810	148	28.4	
503	.600		47.6	0.0220	26.4	87	184.5	970	309	41.2	
504	.600		74.0	0.0343	30.9	86	286.8	1440	779	71.9	
505	.600		99.5	0.0461	62.3	86	385.5	1795	1133	85.5	
506	.600		121.8	0.0564	97.3	86	472.0	1980	1319	82.3	
507	1.302	173	56.1	0.0120	26.9	86	100.2	770	112	26.5	
508	1.302		75.9	0.0162	34.2	85	135.5	805	145	26.5	
509	1.302		102.0	0.0218	68.4	85	182.1	890	230	31.9	
510	1.300		126.4	0.0270	112.9	85	226.1	965	304	33.5	Inlet pressure unsteady
511	1.300		63.4	0.0136	25.4	85	113.4	785	125	20.7	
512	1.300		91.0	0.0194	48.4	85	162.7	855	195	30.7	
513	1.300		113.5	0.0243	78.4	85	203.0	960	280	34.8	
514	1.300		137.3	0.0293	119.4	85	245.6	1010	350	36.6	
515	1.294		150.0	0.0322	149.4	85	269.5	1060	401	38.2	Fuel flow limited
516	.800	79	45.1	0.0157	26.4	79	131.1	785	125	22.5	
517	.800		73.4	0.0255	35.1	79	213.4	1115	455	51.0	
518	.800		99.0	0.0344	71.0	76	287.8	1400	739	67.9	
519	.800		127.0	0.0441	123.9	75	369.1	1635	976	74.0	
520	.800		152.5	0.0530	190.4	74	443.2	1835	1177	77.5	Fuel flow limited
521	.800		30.7	0.0107	25.2	76	89.2	715	55	15.9	
522	1.000	132	40.5	0.0113	24.4	77	94.2	735	75	20.2	
523	1.000		67.3	0.0167	29.4	79	156.4	865	206	33.5	
524	1.000		95.7	0.0266	63.9	79	222.5	1110	451	49.1	
525	1.000		121.3	0.0337	111.4	76	282.0	1275	615	57.6	
526	1.000		154.0	0.0428	193.9	76	358.1	1455	796	61.4	Fuel flow limited
527	1.295		152.0	0.0326	187.9	76	272.9	1070	413	38.2	Fuel flow limited
528	.600	79	124.9	0.0578	121.9	76	484.0	1980	1320	80.5	
529	.600		131.0	0.0607	-----	77	507.6	2000	1338	78.3	Blow-out
530	.600		20.5	0.0095	23.4	77	79.4	735	73	21.2	
531	.800	105	21.1	0.0073	21.3	81	61.3	725	63	95.0	

(l) Methanol; combustor-inlet total temperature, 500° R

532	.600	60	41.0	0.0190	25.9	81	158.9	555	54	7.7	
533	.600		65.9	0.0305	28.9	80	255.4	1075	576	56.8	
534	.600		91.2	0.0422	58.4	80	353.4	1540	1042	81.6	
535	.600		116.6	0.0540	103.0	80	451.8	1755	1255	80.1	
536	.600		133.1	0.0616	-----	80	515.8	1810	1309	74.7	Blow-out
537	1.005	100	83.1	0.0230	47.9	81	192.3	730	231	29.4	
538	1.003		152.1	0.0421	192.4	81	352.5	1180	682	54.0	Fuel flow limited
539	1.003		55.4	0.0153	26.7	80	128.4	535	34	6.0	
540	1.003		121.2	0.0336	109.1	80	280.9	985	484	43.7	
541	1.005		141.4	0.0391	150.8	80	327.1	1120	620	51.1	
542	1.300	130	73.4	0.0157	33.5	80	131.2	630	127	26.3	
543	1.300		101.0	0.0216	70.5	80	180.6	655	155	19.0	
544	1.300		126.9	0.0271	116.2	80	227.0	695	195	20.8	
545	1.300		157.5	0.0337	188.8	80	281.7	815	315	28.7	Fuel flow limited
546	.800	80	54.0	0.0188	25.9	82	156.9	555	55	9.2	
547	.800		75.6	0.0263	36.9	82	219.7	845	344	39.2	
548	.800		100.1	0.0348	71.0	82	290.9	1135	634	57.1	
549	.800		127.5	0.0433	119.7	82	370.5	1370	870	65.6	
550	.800		154.0	0.0535	-----	82	447.5	1560	1059	68.3	Blow-out
551	.800		146.0	0.0507	164.9	80	424.3	1485	985	66.4	Resonance
552	1.300	130	144.0	0.0308	162.9	80	257.5	760	260	25.5	
553	1.300		66.2	0.0142	-----	80	118.4	565	64	12.5	Lean blow-out
554	1.000	100	99.5	0.0276	68.1	81	231.3	455	354	38.8	
555	1.000		36.9	0.0103	-----	81	85.8	520	19	9.9	Lean blow-out
556	.798	80	29.6	0.0103	-----	81	86.2	510	10	7.2	Lean blow-out
557	.595	60	19.4	0.0091	21.9	81	75.8	515	16	7.9	Lean blow-out

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(m) Propylene oxide; combustor-inlet total temperature, 660° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input, Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
558	0.796	105	25.5	0.0089	27.2	64	115.6	1035	375	73.7	
559	.800		36.1	.0125	29.4	64	162.8	1225	566	81.6	
560	.801		45.6	.0153	28.8	64	205.4	1380	720	84.4	
561	.801		62.5	.0217	29.6	60	281.6	1645	986	90.6	
562	.798		96.3	.0335	71.7	58	435.6	2095	1435	92.9	
563	.799		114.3	.0397	88.0	58	516.4	2325	1665	91.6	Resonance
564	.800		123.2	.0428	---	57	555.9	2410	1750	90.9	Blow-out
565	.595	79	35.2	.0164	28.1	64	213.5	1415	754	87.5	
566	.597		51.6	.0240	28.6	63	312.0	1740	1080	97.0	
567	.600		70.4	.0326	28.9	60	423.5	2035	1375	91.7	
568	.600		82.3	.0381	42.0	59	495.1	2220	1560	88.8	Resonance
569	.600		94.1	.0436	61.5	57	566.0	2385	1725	87.8	Resonance
570	.600		106.5	.0493	68.9	56	640.7	2560	1901	87.0	Resonance
571	.600		116.7	.0540	---	58	702.1	2660	2000	85.0	Temperature limited
572	.600		143.7	.0202	28.0	58	262.9	1605	---	93.6	
573	.600		42.9	.0199	28.8	66	258.1	1570	908	90.5	
574	1.303	173	50.7	.0108	30.9	61	140.5	1075	416	66.8	Resonance
575	1.302		65.5	.0140	30.9	58	181.5	1185	525	69.7	
576	1.302		76.9	.0164	31.4	56	213.2	1290	630	75.1	
577	1.301		86.9	.0186	38.4	55	241.0	1385	726	75.5	
578	1.301		99.5	.0212	53.5	54	276.0	1510	850	79.9	
579	1.299		111.3	.0238	69.7	53	309.3	1610	951	80.3	
580	1.299		120.8	.0258	85.2	53	335.6	1695	1036	84.1	
581	1.299		128.5	.0275	96.7	52	357.1	1740	1081	81.5	
582	1.300		146.5	.0313	131.8	52	406.7	1840	1181	79.2	
583	.995	132	38.0	.0106	32.4	65	137.9	1120	459	76.6	
584	.995		57.1	.0159	32.4	64	207.1	1360	698	84.7	
585	.995		78.3	.0219	32.4	62	284.0	1620	959	87.7	
586	.995		92.5	.0258	54.9	62	335.5	1790	1129	93.9	
587	.995		112.5	.0314	88.7	62	408.1	2005	1345	92.9	
588	.995		132.0	.0369	148.8	66	478.8	2175	1514	89.7	
589	.995		140.8	.0393	---	66	510.8	2220	1559	87.2	Blow-out
590	.995		91.0	.0254	66.9	66	330.0	1760	1099	91.4	
591	.995		63.8	.0178	37.8	67	231.4	1460	799	85.3	
592	.597	79	28.2	.0131	26.4	71	170.5	1265	603	83.0	
593	.598		43.2	.0201	27.7	71	260.8	1580	918	90.0	
594	.598		58.4	.0271	30.6	70	352.4	1845	1186	94.0	
595	1.003	132	122.0	.0338	93.0	80	439.1	2060	1398	89.7	
596	1.004		53.3	.0148	33.9	79	191.7	1295	634	82.7	
597	1.003		107.3	.0297	72.8	79	386.1	1920	1259	91.9	
598	1.004		124.3	.0344	---	79	446.9	2090	1429	89.7	
599	1.004		34.4	.0095	32.0	82	123.7	1130	468	83.4	
600	.802	105	33.4	.0116	31.9	83	150.3	1210	546	79.7	
601	.802		83.2	.0288	38.9	80	374.5	1915	1255	94.0	
602	.802		97.1	.0336	56.0	80	437.1	2100	1440	92.9	

(n) Propylene oxide; combustor-inlet total temperature, 500° R

603	0.598	60	49.7	0.0231	28.4	71	299.9	1535	1034	88.4	
604	.598		63.8	.0296	28.6	70	385.0	1825	1325	93.5	Resonance
605	.598		72.8	.0338	31.4	68	439.3	1990	1489	94.4	Resonance
606	.598		82.0	.0381	40.0	66	494.9	2115	1614	92.0	Resonance
607	.598		101.4	.0471	70.0	66	612.0	2375	1874	87.9	
608	.598		116.3	.0540	101.9	67	701.9	2560	2059	86.0	Blow-out
609	.598		57.7	.0268	25.8	68	348.2	1665	1164	88.2	
610	.798	80	35.0	.0122	23.6	70	158.3	1000	498	77.1	
611	.798		68.5	.0238	30.0	70	309.8	1565	1063	89.4	
612	.798		83.7	.0291	45.2	69	378.5	1800	1299	93.5	Resonance

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(n) Concluded. Propylene oxide; combustor-inlet total temperature, 500° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input, Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
613	0.798	80	95.7	0.033	63.5	69	432.8	1965	1463	94.2	Resonance
614	.798	100	113.0	.0393	----	69	511.1	2180	1679	93.0	
615	1.000		47.0	.0131	26.1	65	169.7	990	489	72.1	
616	1.000		67.8	.0188	28.8	65	244.7	1285	785	82.3	
617	1.000		83.0	.0230	37.7	64	299.6	1505	1004	86.2	
618	1.000	130	106.3	.0295	70.9	64	383.7	1800	1300	92.2	Blow-out
619	1.000		124.5	.0348	104.6	64	452.6	1990	1490	91.5	
620	1.000		133.0	.0369	----	65	480.0	1995	1495	86.6	
621	1.303		56.1	.0120	27.6	64	155.4	895	394	65.6	
622	1.303		74.0	.0158	31.1	62	204.9	1045	544	68.0	
623	1.303	130	88.0	.0188	48.2	61	243.8	1210	710	75.2	Fuel flow limited
624	1.304		103.0	.0219	73.1	61	285.1	1375	875	78.4	
625	1.304		119.7	.0255	101.5	62	331.3	1525	1025	80.0	
626	1.302		129.5	.0276	140.1	64	359.0	1575	1075	79.2	
627	1.312		146.9	.0311	----	65	404.1	1685	1185	78.9	
628	1.300	80	154.1	.0329	195.8	65	427.9	1730	1230	77.2	Blow-out
629	.795		72.5	.0253	29.2	68	329.1	1605	1106	88.2	
630	.795		116.8	.0408	92.4	67	530.3	2180	1681	89.7	
631	.794		62.3	.0218	28.9	68	283.3	1480	980	88.5	
632	.995		94.9	.0265	59.7	66	344.2	1665	1165	89.4	
633	.993	60	118.3	.0331	102.8	66	430.0	1925	1425	91.4	Fuel flow limited
634	.597		35.8	.0167	26.1	68	216.5	1225	725	87.2	
635	.800		75.3	.0262	31.6	68	339.8	1650	1150	89.0	
636	.800		63.0	.0219	28.4	66	284.3	1470	970	86.5	
637	1.295		144.4	.0310	151.1	67	402.4	1700	1199	80.0	
638	1.295	130	160.6	.0345	190.4	67	447.6	1735	1234	74.3	Fuel flow limited
639	1.295		132.4	.0284	----	67	369.0	1625	1124	80.7	

(o) Diethyl ether; combustor-inlet total temperature, 660° R

640	1.000	132	33.7	0.0094	32.4	68	136.2	1040	381	70.3	Inlet pressure unsteady
641	1.000		48.6	.0135	34.5	69	196.4	1185	525	75.8	
642	1.000		64.3	.0179	32.9	60	259.9	1355	695	70.5	
643	1.000		80.8	.0224	33.8	58	326.5	1555	895	73.3	
644	1.000		101.2	.0281	50.7	55	409.0	1705	1045	69.9	
645	1.006	105	113.9	.0315	----	55	457.6	1725	1065	63.2	Blow-out
646	1.000		107.1	.0298	57.4	51	432.9	1755	1096	69.4	
647	.799		24.5	.0085	26.4	57	124.0	1055	394	80.4	
648	.799		34.9	.0121	27.6	65	176.5	1210	549	77.7	
649	.799		56.4	.0196	31.6	65	285.3	1555	895	83.4	
650	.799	173	70.6	.0246	34.9	60	357.2	1775	1115	84.5	Blow-out
651	.799		83.3	.0290	35.4	58	421.4	1945	1284	85.0	
652	.803		96.2	.0333	----	58	484.2	2075	1415	82.3	
653	.799		91.8	.0319	39.2	55	464.4	2055	1395	84.5	
654	.802		61.3	.0212	27.9	59	308.9	1660	1000	86.6	
655	1.300	79	29.0	.0062	32.9	73	90.2	900	240	66.7	Slight resonance
656	1.300		55.8	.0119	31.3	69	173.4	970	310	45.0	
657	1.300		76.8	.0164	31.9	63	238.8	1065	405	44.0	
658	1.300		93.4	.0120	41.3	58	290.4	1150	490	44.4	
659	1.300		104.5	.0223	54.2	57	324.9	1165	505	41.2	
660	1.300	79	103.5	.0221	53.4	56	321.8	1195	535	43.6	Blow-out
661	1.300		32.0	.0068	30.3	61	99.5	910	250	65.3	
662	1.300		56.8	.0121	33.4	60	176.6	980	320	45.2	
663	1.300		104.1	.0222	54.4	60	323.6	1165	505	41.0	
664	.600		25.0	.0116	28.6	65	168.3	1200	540	80.6	
665	.600	132	32.3	.0150	26.4	67	217.5	1370	710	84.1	Slight resonance
666	.600		39.6	.0183	30.4	65	266.7	1540	879	87.3	
667	.600		48.8	.0226	30.9	63	328.7	1725	1064	87.4	
668	.600		60.3	.0279	32.2	61	406.2	1935	1275	78.1	
669	.600		73.0	.0338	33.7	59	491.8	2155	1495	86.3	
670	.600	132	77.8	.0360	----	59	524.1	2215	1555	84.7	Blow-out
671	.998		31.0	.0086	29.6	66	125.5	1030	370	75.4	

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs.]

(p) Diethyl ether; combustor-inlet total temperature, 500° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input, Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
672	1.300	130	50.4	0.0108	26.9	58	156.7	815	315	49.7	
673	1.301		69.1	.0148	28.7	56	214.6	960	460	54.4	
674	1.299		88.2	.0189	35.3	53	274.4	1080	580	54.4	
675	1.300		111.3	.0238	63.2	51	346.0	1110	610	45.0	
676	1.298		118.5	.0254	73.0	50	369.0	1110	610	42.4	Blow-out
677	1.299		118.6	.0254	----	50	369.0	1095	585	41.0	Blow-out
678	1.298		102.2	.0219	50.5	51	318.2	1125	625	51.1	
679	.792	80	28.2	.0099	24.4	55	143.9	865	365	59.1	
680	.791		42.1	.0148	25.3	58	215.0	1105	606	71.3	
681	.792		53.9	.0189	26.2	56	275.1	1345	846	80.3	
682	.792		70.2	.0246	30.7	54	358.2	1595	1096	81.3	
683	.790		79.1	.0278	31.9	53	404.6	1715	1215	81.0	
684	.797		84.2	.0294	----	53	427.0	1760	1260	79.8	Blow-out
685	.797		61.2	.0213	29.1	54	310.4	1470	970	81.2	
686	.601	60	24.6	.0114	23.8	60	165.4	985	485	70.9	
687	.601		36.1	.0167	26.5	60	242.7	1235	736	78.6	
688	.601		13.6	.0202	28.6	60	293.2	1470	971	86.5	Resonance
689	.601		56.1	.0259	30.8	58	377.1	1710	1209	86.1	Resonance
690	.601		58.5	.0270	30.1	56	393.3	1745	1247	85.2	Resonance
691	1.000	100	42.1	.0117	29.0	59	170.1	885	385	57.7	
692	1.000		54.7	.0152	27.0	58	221.0	1090	590	67.4	
693	1.000		67.2	.0187	27.4	56	271.6	1255	754	71.3	
694	1.000		82.5	.0229	32.1	55	333.5	1415	914	72.7	
695	1.000		97.7	.0271	45.3	55	394.9	1455	955	64.1	Blow-out
696	.981		104.8	.0297	----	55	431.7	1420	921	57.7	Blow-out

(q) Carbon disulfide; combustor-inlet total temperature, 660° R

697	0.600	79	29.3	0.0136	21.4	61	79.1	885	225	71.2	
698	.600		35.6	.0165	21.9	62	96.1	940	288	75.1	
699	.601		40.8	.0188	22.0	62	109.8	1010	350	76.7	
700	.601		64.3	.0297	26.3	64	173.2	1220	560	82.7	
701	.601		88.4	.0409	27.3	65	238.2	1425	765	82.3	
702	.602		118.3	.0546	35.0	62	318.1	1650	991	81.6	
703	.602		149.0	.0688	62.6	59	400.9	1850	1191	79.2	
704	.603		174.3	.0803	93.5	58	468.1	2020	1361	79.9	
705	.596		190.0	.0885	116.4	58	516.2	2110	1450	77.9	
706	.595		203.5	.0950	138.9	56	553.8	2210	1551	78.5	Fuel flow limited
707	.800	105	33.5	.0116	23.1	61	67.8	870	211	71.8	
708	.801		58.2	.0202	26.5	64	117.7	1035	376	81.0	
709	.800		84.9	.0294	27.3	65	171.6	1210	549	81.5	
710	.800		118.1	.0410	35.9	63	239.0	1425	763	82.5	
711	.800		148.3	.0515	64.4	60	300.2	1605	946	82.2	
712	.800		43.4	.0151	26.9	70	87.9	950	290	76.5	
713	.800		150.3	.0522	121.9	58	304.2	1630	970	81.6	
714	.795		165.0	.0577	154.9	56	336.1	1795	1035	81.1	
715	.792		181.1	.0635	151.4	56	370.3	1880	1120	80.3	
716	.793		187.1	.0655	172.2	55	382.0	1810	1150	80.4	Fuel flow limited
717	1.305	173	51.6	.0110	28.8	65	64.0	860	202	71.8	Inlet pressure unsteady
718	1.305		85.6	.0182	28.9	67	106.2	985	327	73.6	
719	1.302		120.3	.0257	47.0	62	149.7	1135	475	79.7	
720	1.303		160.6	.0342	98.6	59	199.6	1290	630	81.5	
721	1.303		181.3	.0387	131.4	55	225.3	1365	705	80.2	
722	1.302		194.0	.0414	160.4	54	241.3	1415	756	80.4	Fuel flow limited
723	.799	105	117.0	.0407	44.2	64	237.2	1415	755	82.0	
724	.798		155.8	.0542	93.9	16	316.0	1640	929	81.3	
725	.799		192.1	.0668	158.4	16	389.4	1820	1160	79.9	Fuel flow limited
726	.798		77.0	.0268	27.3	16	156.2	1170	510	82.8	

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(r) Carbon disulfide; combustor-inlet total temperature, 500° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input, Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
727	1.301	130	90.5	0.0193	----	62	112.6	825	325	73.2	
728	1.301		117.4	.0251	----	61	146.1	955	454	77.5	
729	1.300		148.0	.0316	----	60	184.3	1100	600	81.5	
730	1.300		174.0	.0372	----	59	216.8	1215	715	81.7	
731	1.300		203.5	.0435	----	58	253.5	1335	834	84.1	
732	.802	80	49.1	.0170	----	62	99.2	800	300	77.3	
733	.802		71.3	.0247	----	62	144.0	965	465	81.2	
734	.800		102.5	.0356	----	62	207.5	1195	695	84.6	
735	.800		132.2	.0459	----	60	267.6	1400	900	86.4	
736	.800		154.2	.0535	----	60	312.1	1535	1035	86.3	
737	.802	60	178.0	.0617	----	60	359.5	1665	1165	85.0	
738	.801		204.0	.0707	----	60	412.4	1810	1310	83.9	
739	.600		44.2	.0205	21.6	65	119.3	860	362	75.7	
740	.604		62.0	.0285	23.9	65	166.3	1045	545	81.0	
741	.600		85.1	.0394	25.6	66	229.7	1245	746	82.1	
742	.600	↓	110.5	.0512	30.4	64	298.3	1460	960	83.1	
743	.599		135.0	.0626	51.7	60	365.1	1655	1155	82.9	
744	.598		165.2	.0767	83.5	59	447.3	1845	1345	80.0	
745	.598		187.3	.0870	114.4	58	507.2	1985	1486	78.2	
746	.598		204.5	.0950	141.9	58	553.7	2075	1575	77.9	Fuel flow limited

(s) Acetone; combustor-inlet total temperature, 660° R

747	0.600	79	23.5	0.0109	23.1	77	131.6	960	297	54.0	
748	.600		39.0	.0181	29.8	77	218.4	1170	509	60.0	
749	.600		50.9	.0236	27.9	75	284.9	1540	879	80.3	
750	.600		62.8	.0291	28.7	75	351.6	1790	1130	87.4	
751	.600		76.9	.0356	----	75	430.5	1955	1294	83.4	Resonance
752	.600	↓	73.0	.0338	33.0	75	408.8	1930	1269	86.7	Resonance
753	1.003		37.4	.0104	28.2	77	125.3	920	260	52.5	
754	1.003		53.7	.0149	29.0	77	179.8	1050	390	54.6	
755	1.003		65.9	.0183	28.3	77	220.7	1210	550	65.1	
756	1.003		77.1	.0214	34.3	77	258.2	1335	675	66.0	
757	.996	↓	93.2	.0260	56.4	74	314.3	1500	840	69.7	
758	.996		108.4	.0302	81.0	74	365.6	1575	915	66.6	
759	.996		122.8	.0342	----	74	414.1	1525	866	55.7	Blow-out
760	.801		43.9	.0152	27.3	80	184.1	1100	440	60.0	
761	.801		23.1	.0080	24.4	80	96.9	900	239	59.5	
762	.802	↓	63.2	.0219	28.4	80	264.7	1470	809	78.4	
763	.802		77.6	.0269	36.4	80	325.1	1650	989	81.2	
764	.802		93.4	.0324	60.4	77	391.2	1825	1165	81.2	
765	.802		107.4	.0372	----	77	449.9	1825	1164	70.4	Blow-out
766	1.300		37.2	.0079	28.6	77	96.1	850	188	52.5	
767	1.300	↓	53.5	.0114	29.4	77	138.2	890	229	42.2	
768	1.300		75.2	.0161	32.9	77	194.4	990	330	44.2	
769	1.300		99.3	.0212	66.8	77	256.6	1135	473	48.0	
770	1.300		135.1	.0289	----	77	349.2	1125	464	34.0	Blow-out
771	1.300		100.0	.0214	68.9	77	258.4	1145	484	48.1	
772	1.300	↓	122.8	.0262	118.0	77	317.3	1190	529	42.6	
773	1.002		63.5	.0176	28.9	84	212.9	1155	494	59.9	
774	1.002		87.2	.0242	35.4	84	292.4	1415	754	65.8	
775	1.002		117.4	.0326	75.6	84	393.7	1610	949	65.3	
776	1.002		124.3	.0345	85.8	84	416.8	1570	908	59.0	
777	1.000	↓	129.9	.0361	----	84	436.4	1525	864	53.0	Blow-out
778	1.302		76.1	.0162	30.4	84	196.4	965	305	17.7	
779	1.302		112.4	.0240	77.0	84	290.0	1145	485	42.3	
780	1.302		141.8	.0303	----	84	365.8	1150	491	34.6	Blow-out
781	1.000		53.0	.0147	27.0	84	178.0	1060	400	55.6	

TABLE II. - Continued. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(s) Concluded. Acetone; combustor-inlet total temperature, 660° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input, Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
782	1.073	132	103.2	0.0267	62.4	84	323.0	1555	895	73.3	Blow-out
783	1.010		35.0	.0096	31.0	86	116.4	930	270	55.8	
784	1.010		125.6	.0345	----	86	417.7	1540	880	56.3	
785	.600	79	35.4	.0164	27.4	86	198.2	1245	584	77.5	
786	.600		45.3	.0210	28.4	86	253.6	1445	783	78.3	
787	.585		76.0	.0361	----	86	436.5	1960	1298	82.4	Blow-out
788	1.298	173	37.0	.0079	30.4	86	95.8	850	189	51.5	
789	1.298		75.9	.0162	31.4	85	196.4	955	294	39.4	Blow-out
790	1.298		114.5	.0245	79.1	85	296.3	1160	499	42.8	
791	1.298		141.8	.0303	----	85	366.9	1140	479	33.9	
792	1.298		135.5	.0290	117.9	85	350.7	1210	549	40.1	
793	1.298		40.1	.0086	30.4	85	103.8	855	193	47.5	Blow-out
794	1.298		83.4	.0179	33.8	86	215.9	995	334	41.3	
795	1.298		90.4	.0194	43.4	86	234.0	1045	384	42.1	
796	1.298		121.8	.0261	91.9	86	315.2	1180	520	42.2	
797	1.298		142.5	.0305	----	86	368.7	1145	492	33.6	

(t) Acetone; combustor-inlet total temperature, 500° R

798	0.600	60	39.9	0.0185	27.4	77	223.4	970	471	52.9	Resonance Blow-out
799	.600		23.1	.0107	22.8	77	129.3	700	201	39.7	
800	.600		50.5	.0234	26.9	77	282.8	1245	746	67.0	
801	.600		63.5	.0294	28.8	77	355.6	1600	1097	82.1	
802	.600		74.1	.0343	----	77	414.9	1660	1160	75.4	
803	.800	80	35.0	.0122	25.3	79	146.9	730	230	41.3	Blow-out
804	.800		24.5	.0085	22.0	79	102.9	655	155	33.9	
805	.800		56.1	.0195	26.9	79	235.6	1035	535	57.8	
806	.800		74.4	.0258	32.4	79	312.4	1325	825	66.7	
807	.800		92.5	.0321	55.9	79	388.5	1595	1095	75.4	
808	.800	100	100.4	.0349	----	79	421.6	1630	1130	72.5	
809	.999		33.8	.0094	23.7	81	113.7	660	161	34.2	
810	.999		51.7	.0144	25.0	81	173.9	785	286	40.1	Blow-out
811	.999		71.7	.0199	28.4	80	241.2	970	470	49.9	
812	.999		98.5	.0274	55.3	80	331.3	1260	760	58.6	
813	1.026	130	123.1	.0333	96.5	80	403.0	1350	851	55.7	
814	1.003		120.7	.0334	92.8	80	404.3	1410	910	59.5	
815	1.003		129.2	.0358	----	80	432.7	1290	790	47.8	
816	1.300		57.2	.0122	26.0	80	147.8	690	190	33.2	
817	1.300		35.6	.0076	23.9	80	92.0	640	141	36.4	Blow-out
818	1.300		88.0	.0188	37.6	80	227.4	805	306	35.3	
819	1.300		117.5	.0251	82.3	80	303.7	980	481	38.6	
820	1.300		144.8	.0309	----	80	374.2	965	465	34.9	
821	1.300		65.4	.0140	27.1	84	169.0	715	215	30.8	
822	1.300		104.9	.0224	63.9	84	271.0	915	415	37.4	
823	1.300	80	135.5	.0290	117.4	84	350.1	1005	504	36.4	
824	1.308	130	143.5	.0307	----	84	370.8	965	463	34.2	Blow-out
825	.801		45.0	.0156	26.4	84	188.7	895	394	54.7	
826	1.298		38.7	.0083	26.2	86	100.2	655	155	39.3	
827	1.298		93.7	.0201	48.1	86	242.5	865	364	35.5	

(u) Butylsilane; combustor-inlet total temperature, 660° R

828	1.300	173	54.2	0.0116	30.4	83	212.7	1400	740	90.7	Exhaust limited
829	1.300		30.0	.0064	30.3	85	117.6	1080	420	84.4	
830	1.300		74.7	.0160	48.4	85	293.1	1580	920	83.0	
831	1.300		103.6	.0221	98.8	84	406.4	1940	1280	86.0	
832	1.300		109.4	.0234	107.4	85	429.4	1975	1318	83.2	
833	.600	79	22.0	.0102	29.5	86	187.0	1330	670	95.8	Temperature limited
834	.600		61.1	.0283	39.4	86	519.6	2040	1379	73.5	
835	.600		120.1	.0556	147.4	86	1021.0	2685	2024	60.9	

TABLE II. - Concluded. PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH HYDROCARBON AND NONHYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 in. Hg abs]

(v) Butylsilane; combustor-inlet total temperature, 500° R

Run	Air flow, lb/sec	Combustor-inlet reference velocity (nominal), ft/sec	Fuel flow, lb/hr	Fuel-air ratio	Fuel-nozzle differential pressure, lb/sq in.	Fuel temperature, °F	Heat input, Btu/lb air	Mean combustor-outlet temperature, °R	Mean temperature rise through combustor, °F	Combustion efficiency, percent	Remarks
836	1.300	130	34.7	0.0074	30.8	89	136.1	970	471	91.5	Exhaust limited Resonance Resonance
837	1.300	↓	96.0	.0205	89.0	83	376.7	1630	1129	80.9	
838	1.300	↓	124.0	.0265	144.4	83	486.7	1925	1424	79.6	
839	1.300	↓	123.1	.0263	-----	83	483.0	1955	1454	82.0	
840	.600	60	71.9	.0333	49.4	85	611.4	2070	1569	71.4	
841	.600	↓	117.1	.0542	148.4	84	995.6	2755	2254	67.8	
842	.600	↓	29.1	.0135	-----	84	247.4	1400	902	94.9	

(w) Acrylonitrile; combustor-inlet total temperature, 650° R

843	1.300	173	68.5	0.0146	30.4	79	201.2	1080	420	53.4	Resonance Blow-out
844	.594	79	24.8	.0116	27.4	81	159.4	1140	479	76.1	
845	.594	↓	53.1	.0248	26.8	81	341.3	1790	1130	88.5	
846	.594	↓	91.7	.0429	80.4	81	589.3	2460	1800	87.8	
847	.594	↓	115.0	.0538	102.4	81	739.5	2540	1800	74.5	
848	1.301	173	31.8	.0068	26.8	81	93.3	845	187	43.5	Fuel flow limited Resonance Resonance Resonance Resonance
849	1.301	↓	76.6	.0164	29.9	80	224.6	1090	431	47.8	
850	1.301	↓	123.0	.0263	114.4	78	360.8	1510	848	62.4	
851	.598	79	72.3	.0336	36.3	79	461.4	2075	1415	85.0	
852	.598	↓	49.7	.0231	30.6	80	317.1	1730	1071	89.7	
853	.598	↓	70.8	.0329	35.3	80	451.8	2075	1418	87.1	
854	1.300	173	92.3	.0197	75.4	80	271.0	1280	620	58.7	

(x) Acrylonitrile; combustor-inlet total temperature, 500° R

855	1.301	130	36.8	0.0079	26.8	77	108.0	630	130	30.2	Fuel flow limited
856	1.298	↓	71.0	.0152	32.6	77	208.7	855	355	42.4	
857	1.298	↓	129.7	.0278	119.4	76	381.4	1260	760	54.4	
858	1.298	↓	93.2	.0199	75.4	77	274.0	1055	555	52.0	
859	.598	60	27.2	.0126	26.8	78	173.5	965	464	68.6	
860	.598	↓	55.9	.0260	30.3	77	356.7	1660	1158	84.9	Resonance Resonance Blow-out Resonance
861	.598	↓	95.7	.0445	79.7	77	610.7	2285	1785	82.8	
862	.598	↓	112.0	.0520	92.4	77	710.4	2345	1845	73.6	
863	.598	↓	73.8	.0343	53.4	78	471.0	2070	1570	92.0	

(y) Acrolein; combustor-inlet total temperature, 660° R

864	1.300	173	59.9	0.0128	26.2	82	152.2	1030	370	59.8	Fuel flow limited
865	1.300	↓	68.5	.0146	27.4	85	174.0	1120	461	67.1	
866	1.300	↓	98.9	.0211	57.4	85	251.2	1410	751	79.0	
867	1.300	↓	140.3	.0300	132.4	85	356.4	1705	1053	79.3	
868	.600	79	49.0	.0227	31.1	85	269.7	1435	773	74.9	
869	.600	↓	29.7	.0138	27.8	85	163.5	1145	484	74.9	Blow-out
870	.600	↓	58.9	.0273	31.9	86	324.2	1670	1008	83.8	
871	.600	↓	87.1	.0403	41.9	85	479.3	2095	1435	85.0	
872	.600	↓	128.5	.0595	-----	85	707.3	2630	1969	83.5	

(z) Acrolein; combustor-inlet total temperature, 500° R

873	1.300	130	38.4	0.0082	31.3	82	97.5	670	169	48.4	Fuel flow limited
874	1.300	↓	57.0	.0122	31.0	83	144.8	760	260	44.5	
875	1.300	↓	85.3	.0182	42.4	83	216.7	1030	530	63.0	
876	1.300	↓	141.6	.0303	94.0	83	359.7	1525	1025	75.4	
877	1.300	↓	107.2	.0229	69.4	83	272.4	1280	780	74.2	
878	.598	60	31.0	.0144	26.4	83	171.2	1020	520	77.0	Blow-out Resonance
879	.598	↓	50.1	.0233	30.4	83	276.6	1385	885	83.5	
880	.598	↓	77.8	.0361	37.4	83	429.6	1900	1400	89.2	
881	.598	↓	128.8	.0599	-----	83	711.7	2485	1986	82.5	
882	.598	↓	97.6	.0453	74.4	83	538.9	2270	1770	93.6	

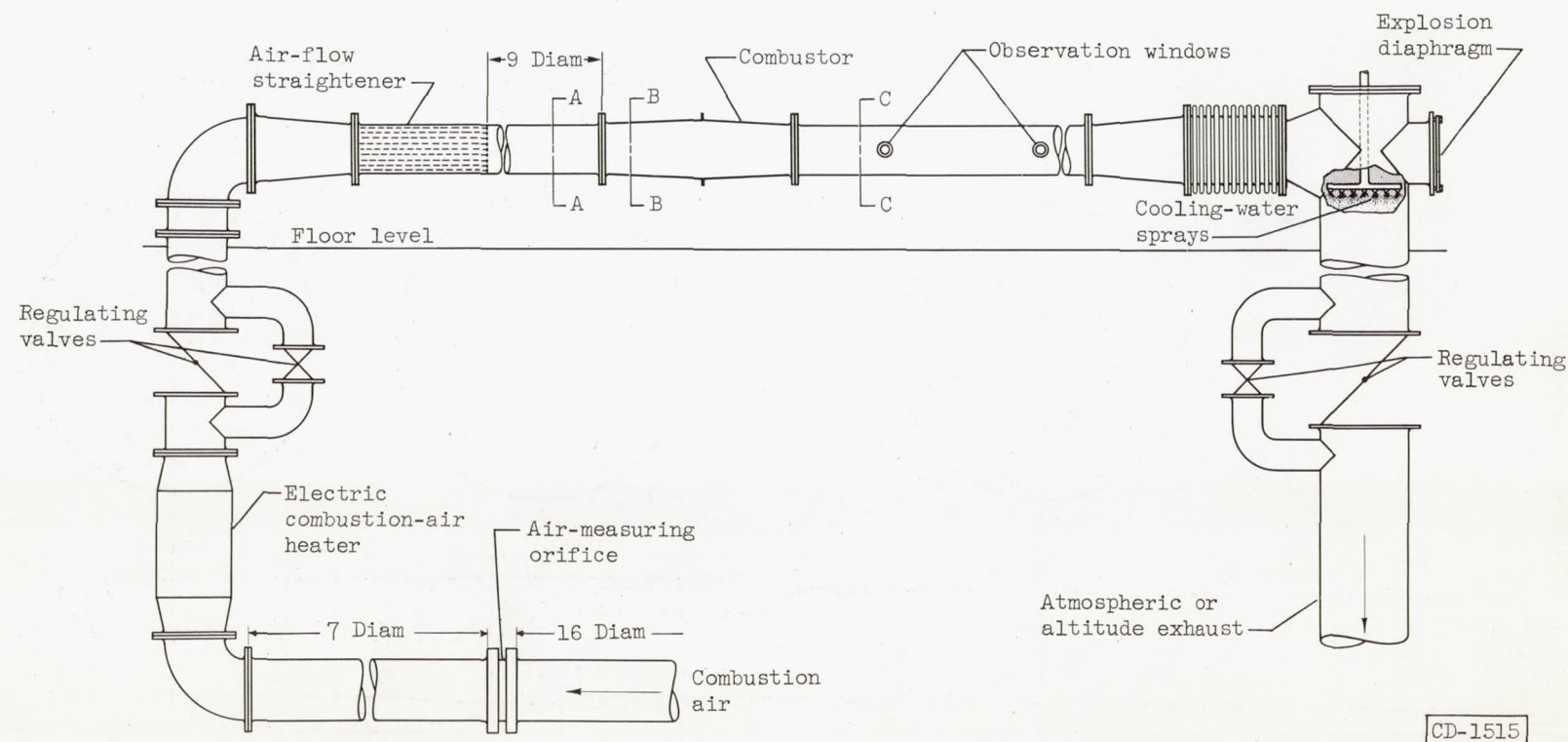


Figure 1. - Single combustor installation and auxiliary equipment. Instrumentation planes, A-A, B-B, and C-C.

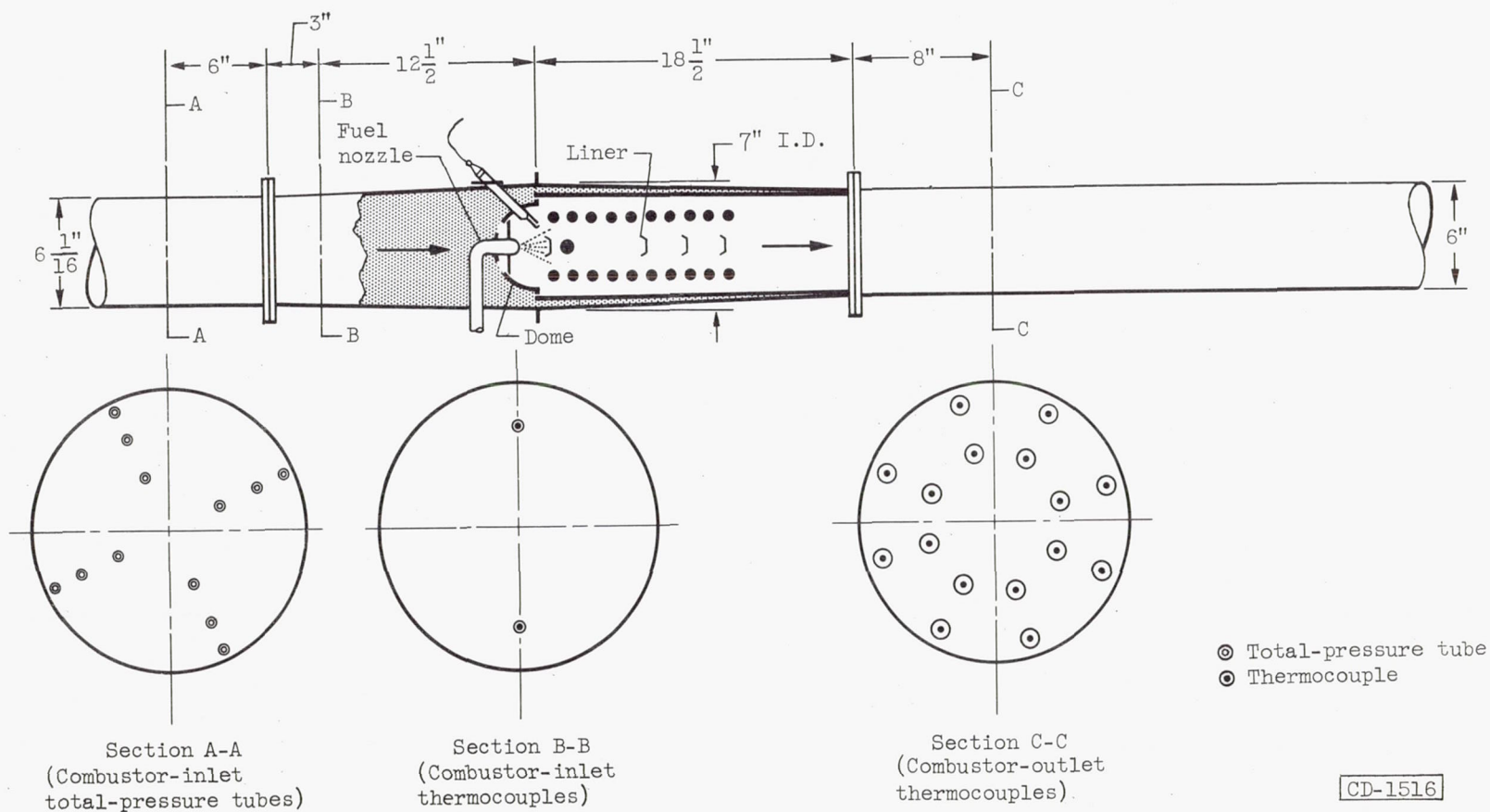


Figure 2. - Cross section of single combustor installation showing auxiliary ducting and location of temperature- and pressure-measuring instruments in instrumentation planes.

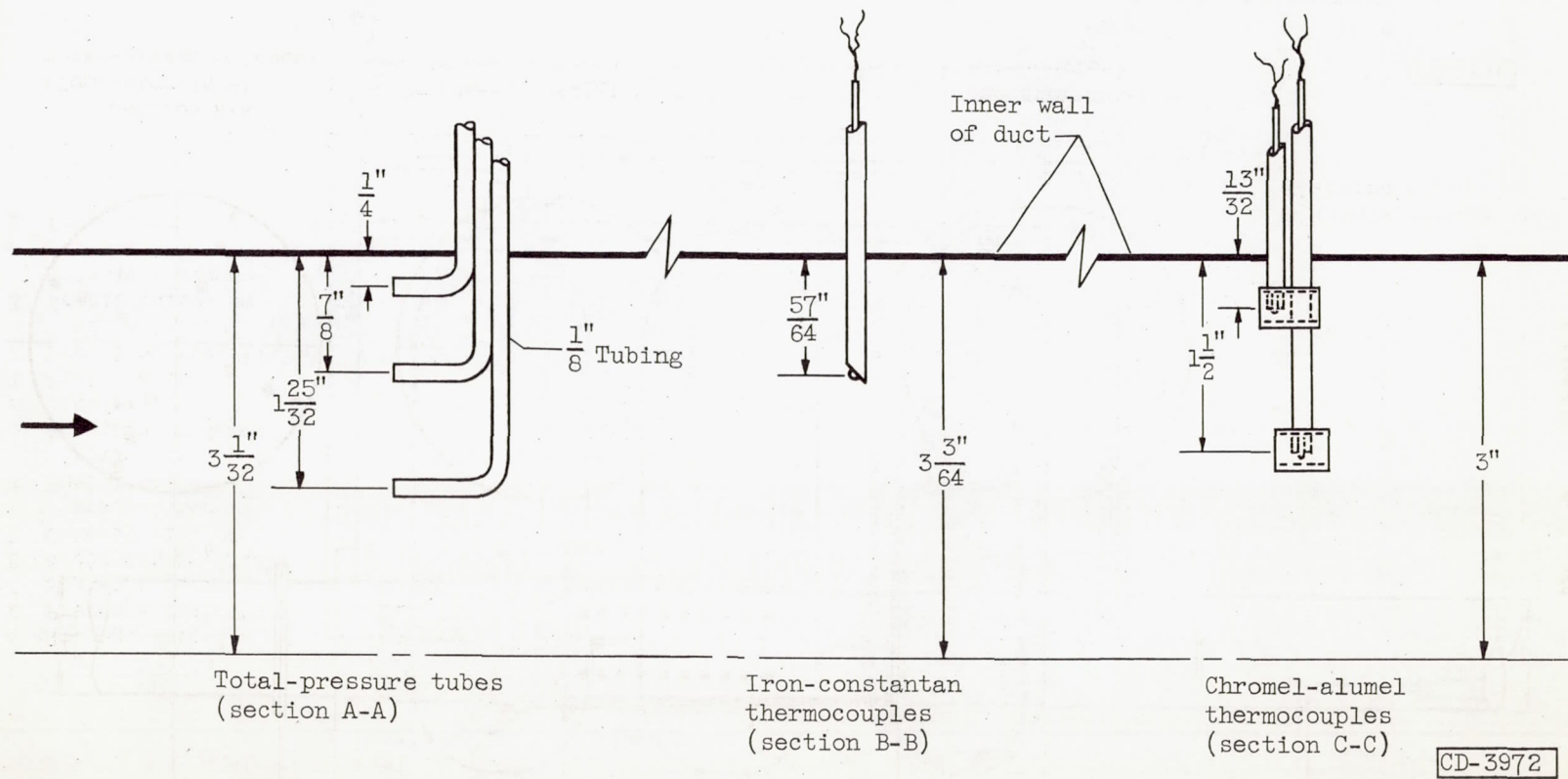
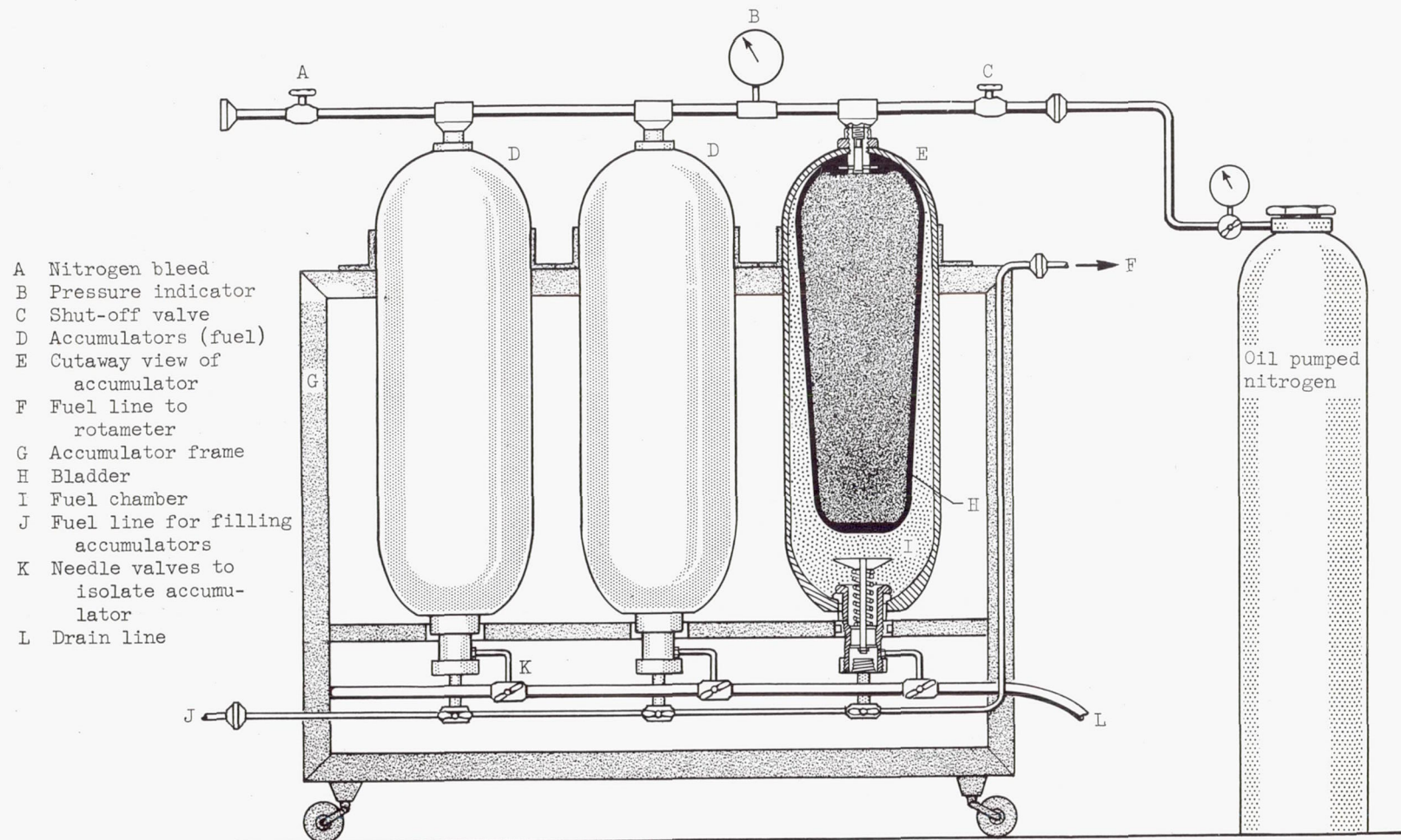


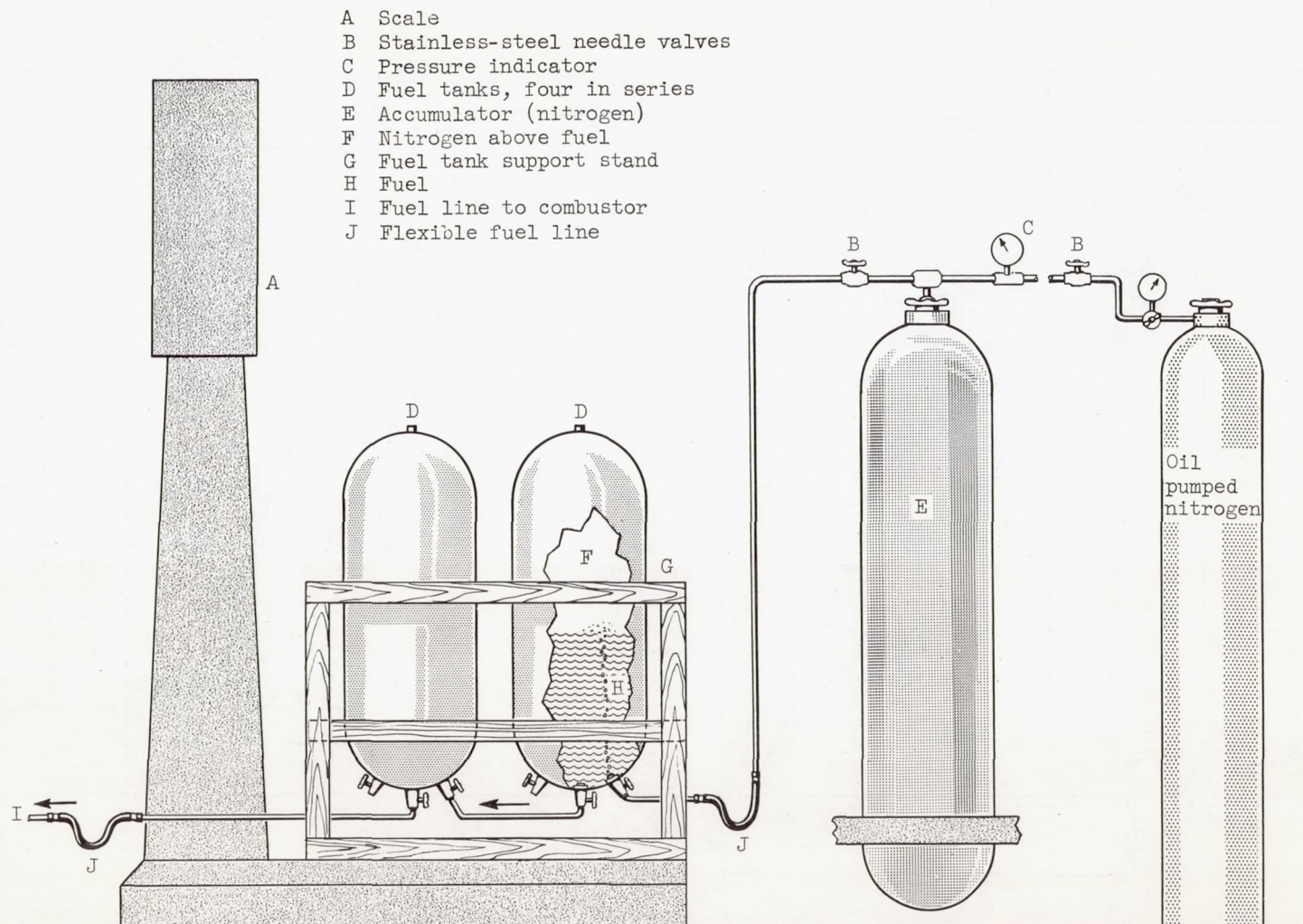
Figure 3. - Construction details of temperature- and pressure-measuring instruments.



(a) Fuel accumulators, showing detail of bladder and valve.

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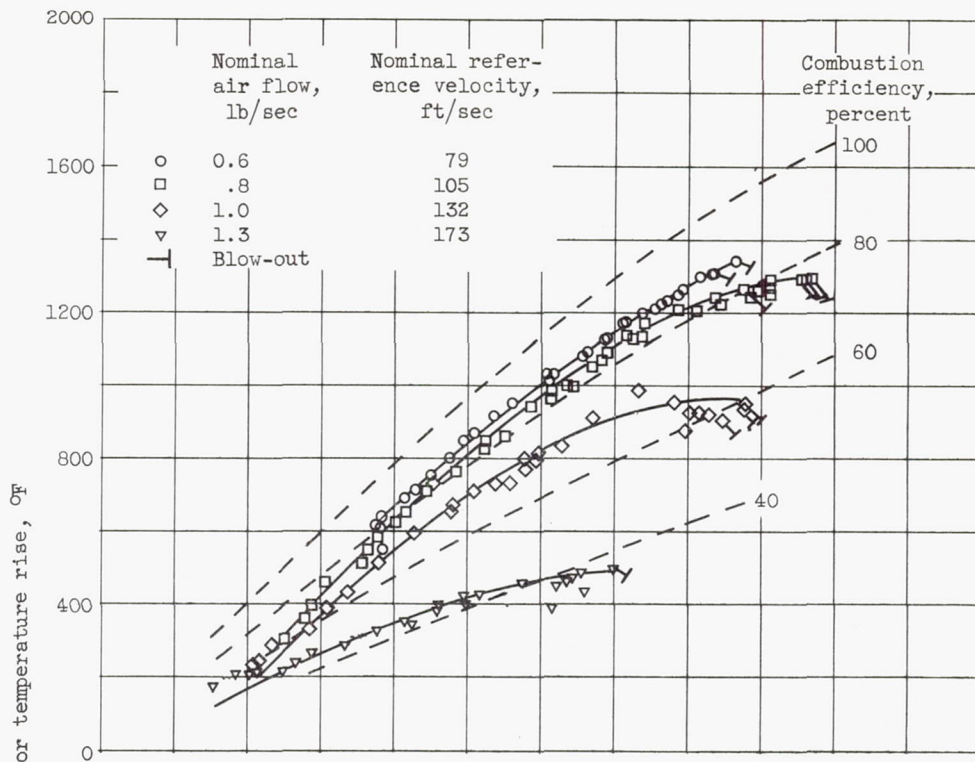
Figure 4. - Schematic diagram of pressurized fuel system and auxiliary equipment.



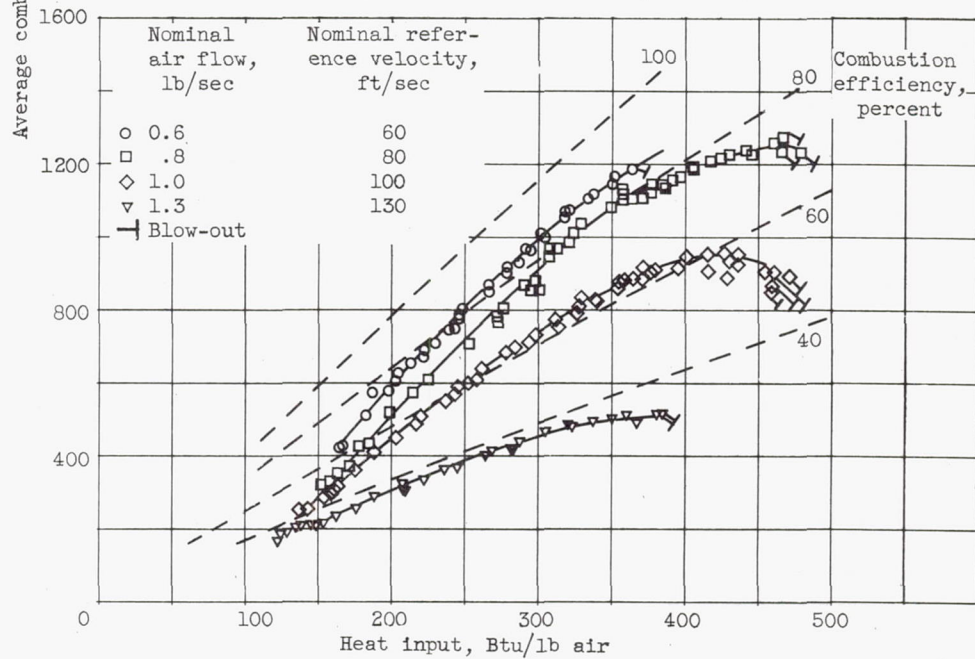
(b) Fuel system and auxiliary equipment for metering flow of toxic fuels.

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Figure 4. - Concluded. Schematic diagram of pressurized fuel system and auxiliary equipment.



(a) Inlet-air temperature, 200° F.



(b) Inlet-air temperature, 40° F.

Figure 5. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, isooctane.

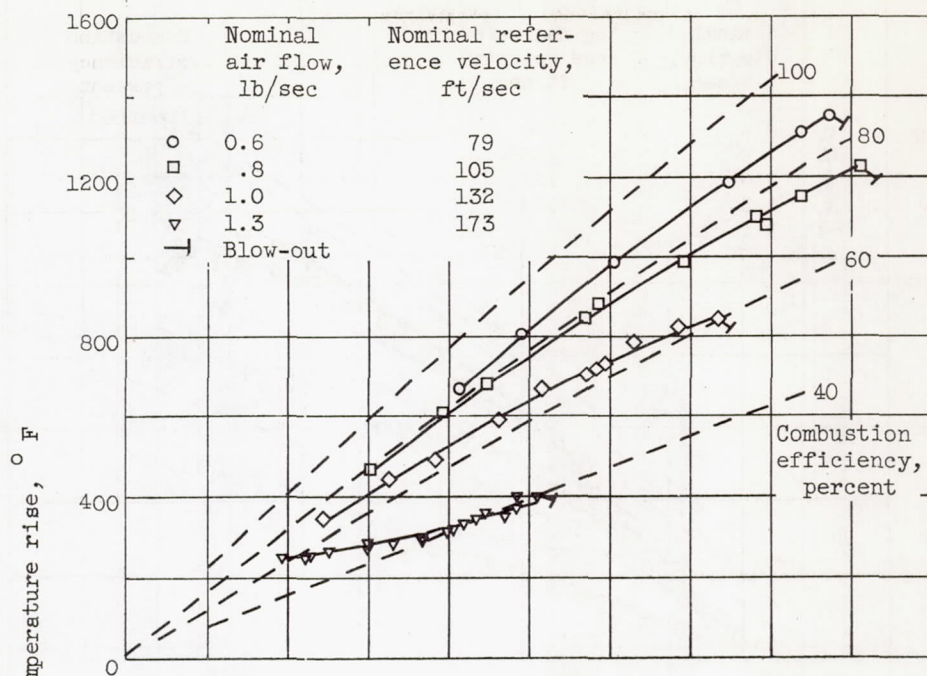
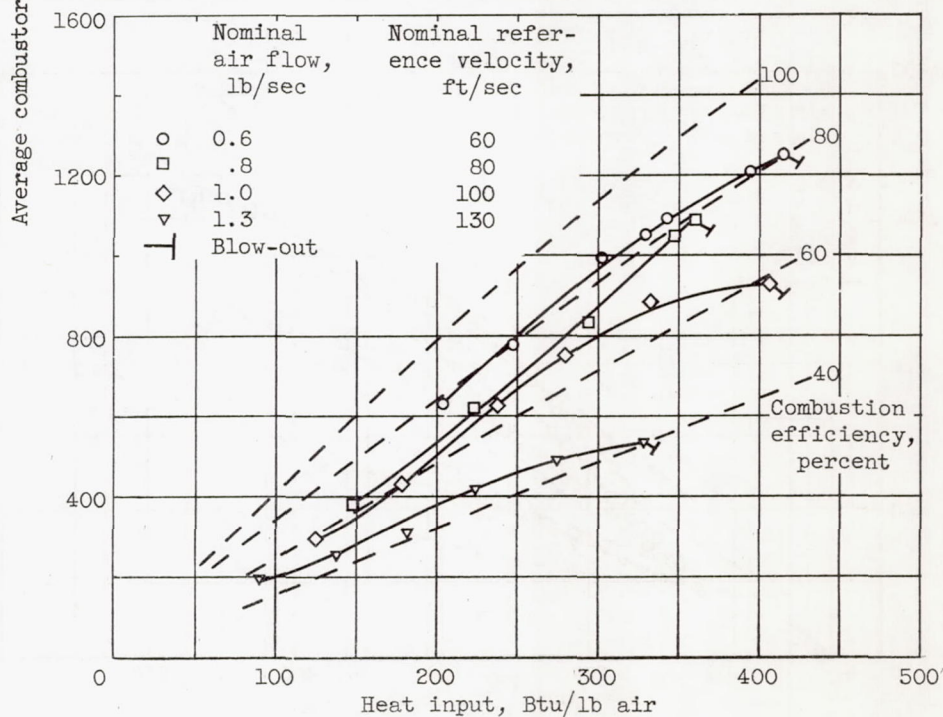
(a) Inlet-air temperature, 200°F .(b) Inlet-air temperature, 40°F .

Figure 6. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, n-pentane.

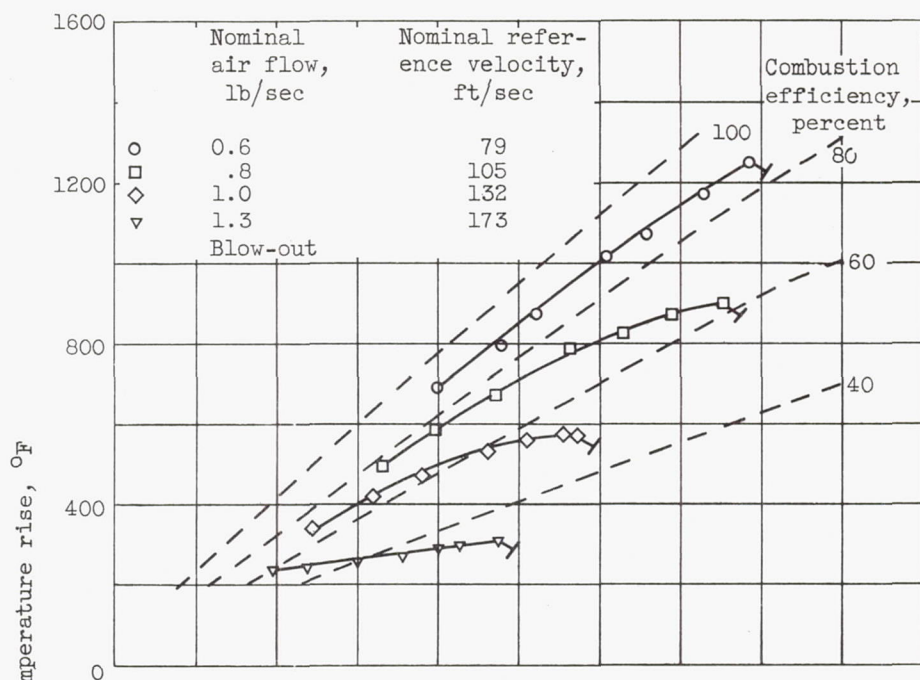
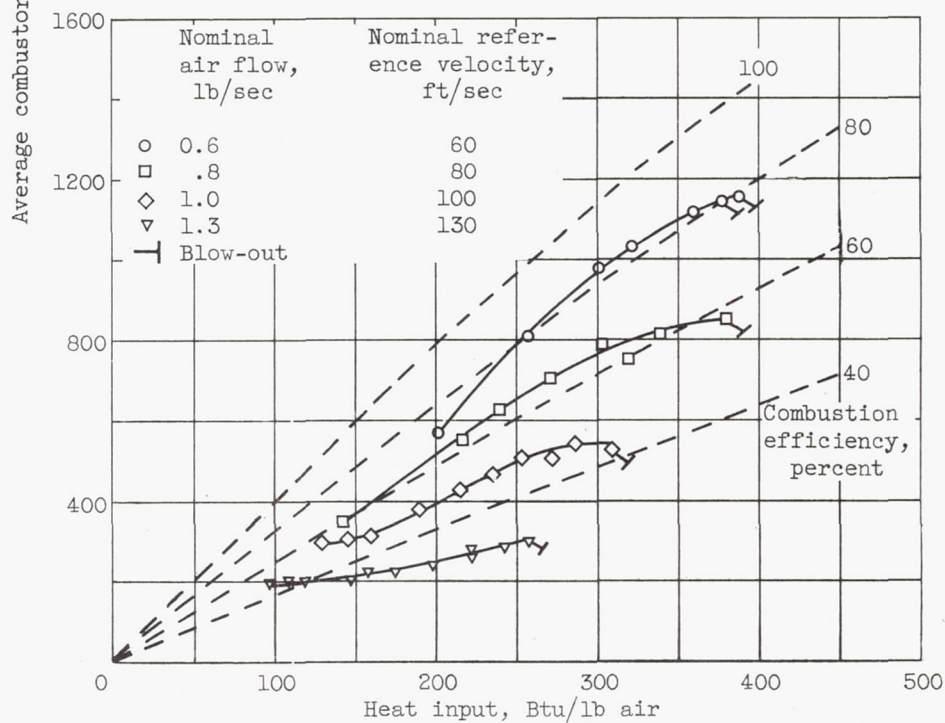
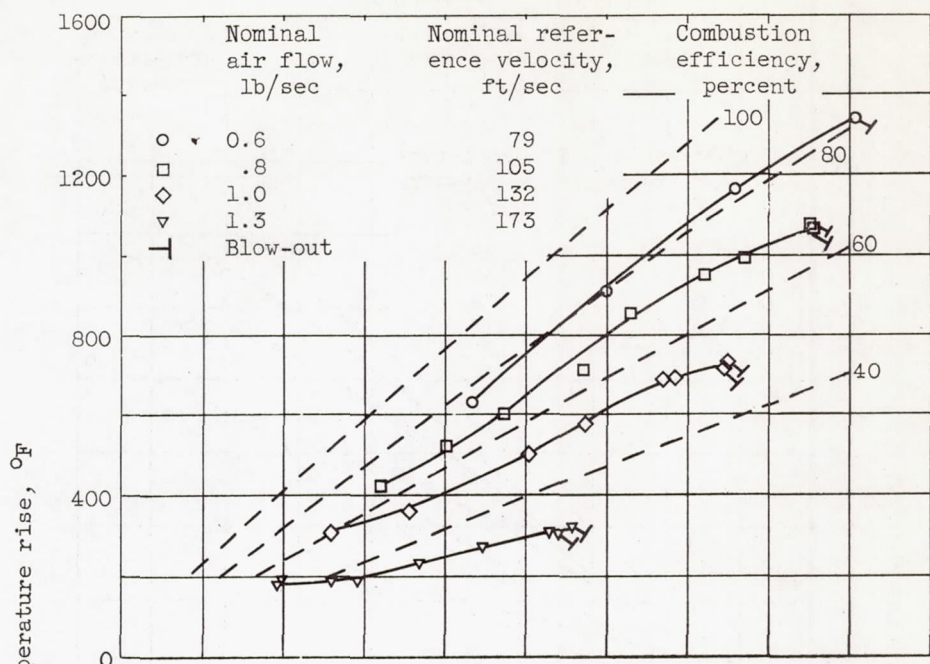
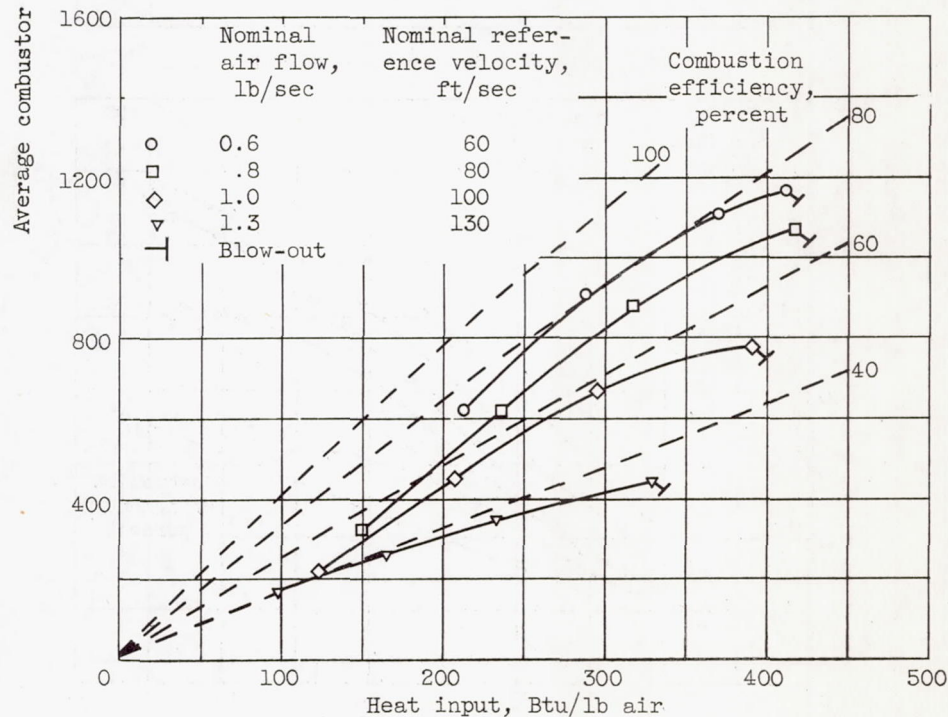
(a) Inlet-air temperature, 200°F .(b) Inlet-air temperature, 40°F .

Figure 7. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, isopentane.

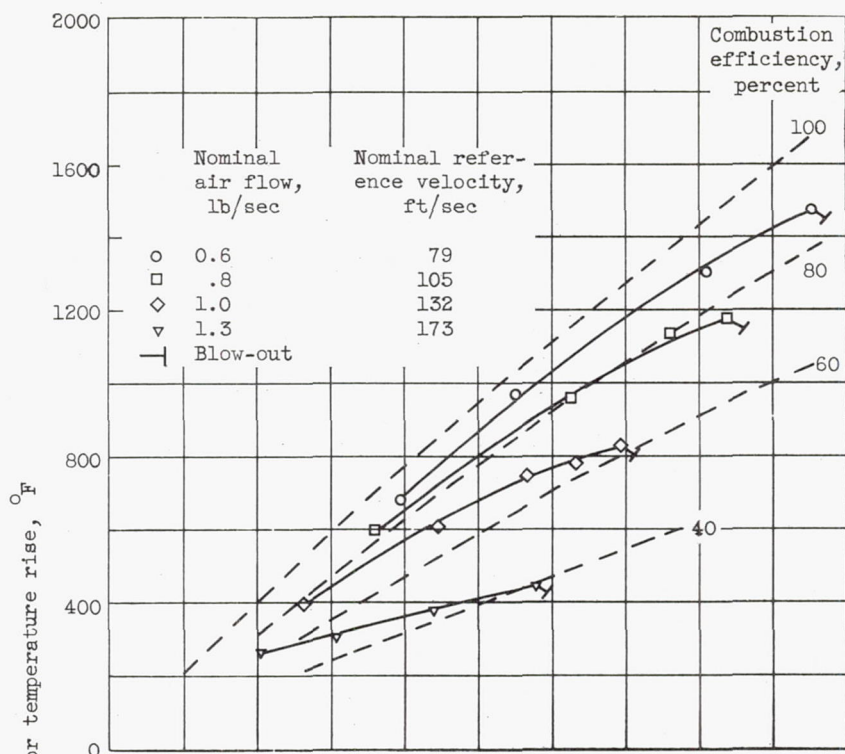


(a) Inlet-air temperature, 200°F .

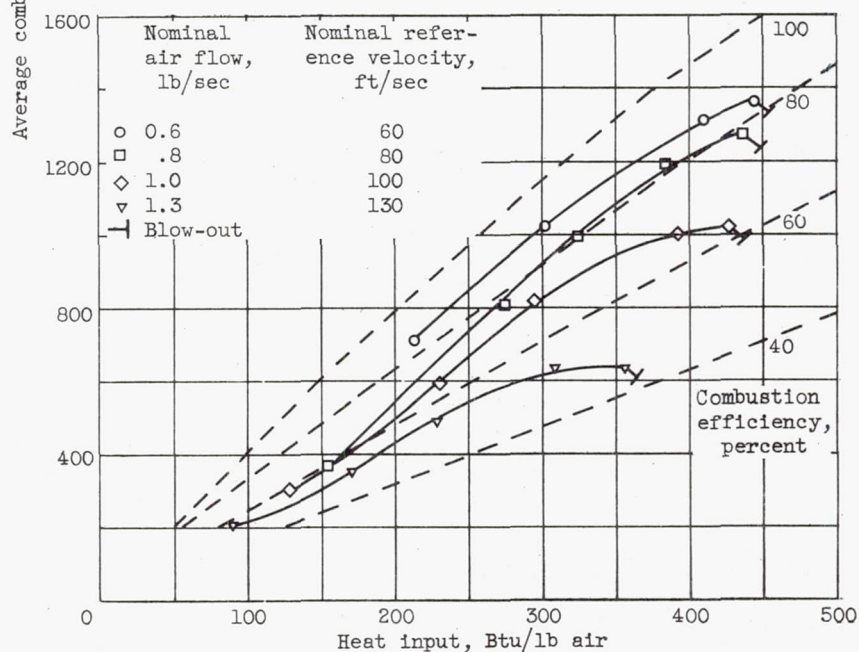


(b) Inlet-air temperature, 40°F .

Figure 8. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, 2,2-dimethylbutane.

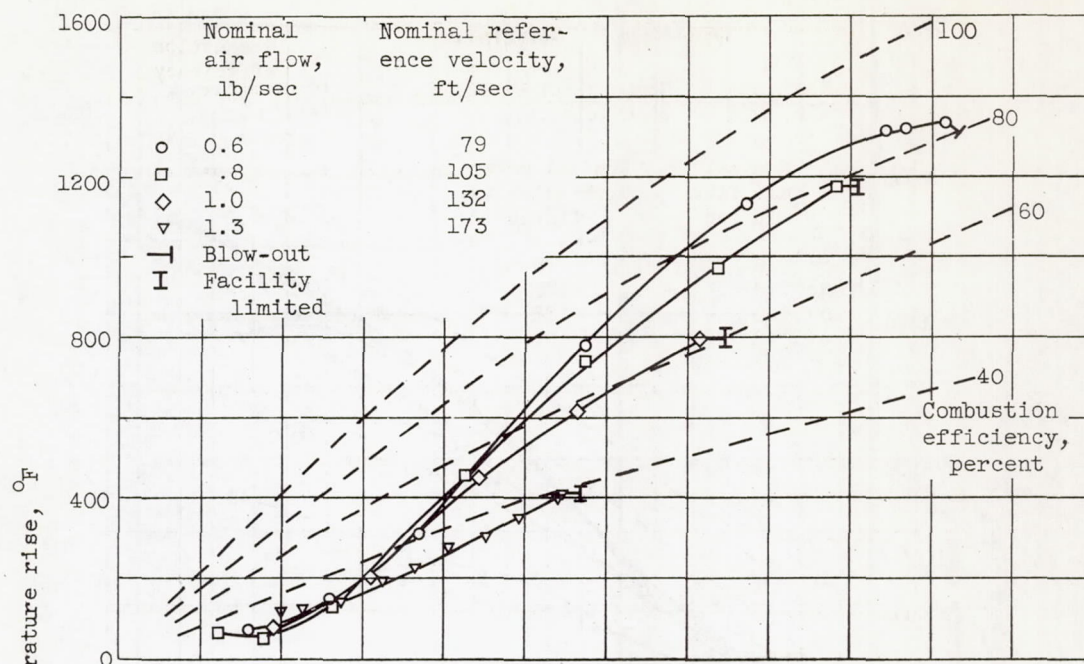


(a) Inlet-air temperature, 200° F.

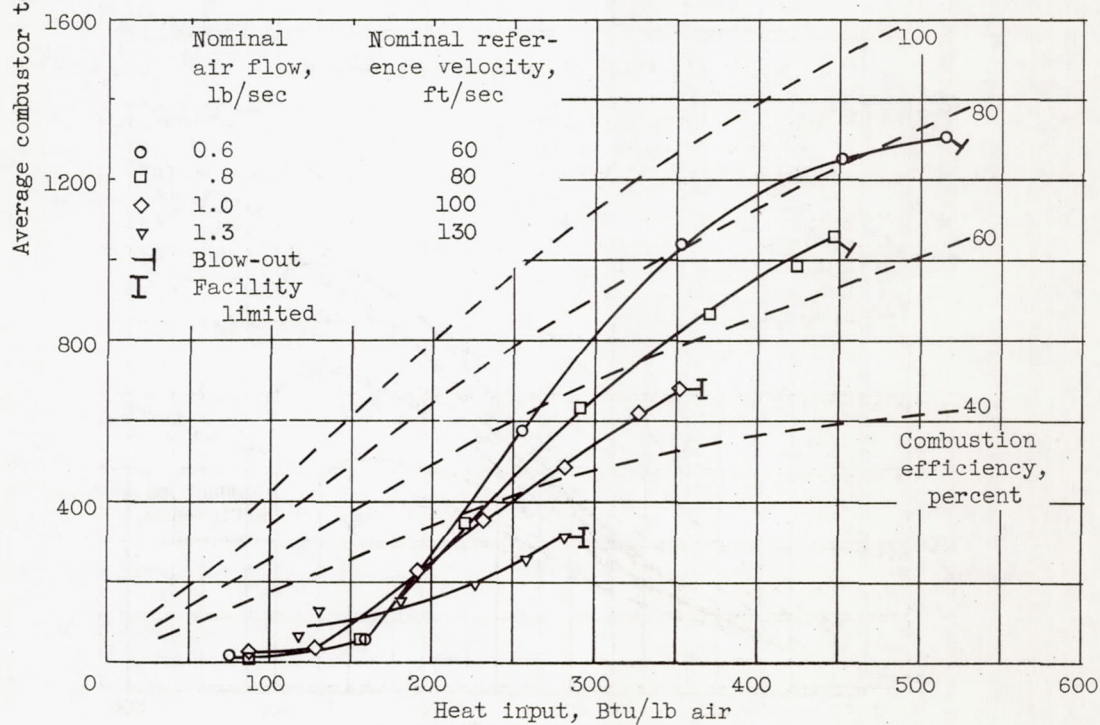


(b) Inlet-air temperature, 40° F.

Figure 9. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow Fuel, 2-pentene.



(a) Inlet-air temperature, 200° F.



(b) Inlet-air temperature, 40° F.

Figure 10. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, methanol.

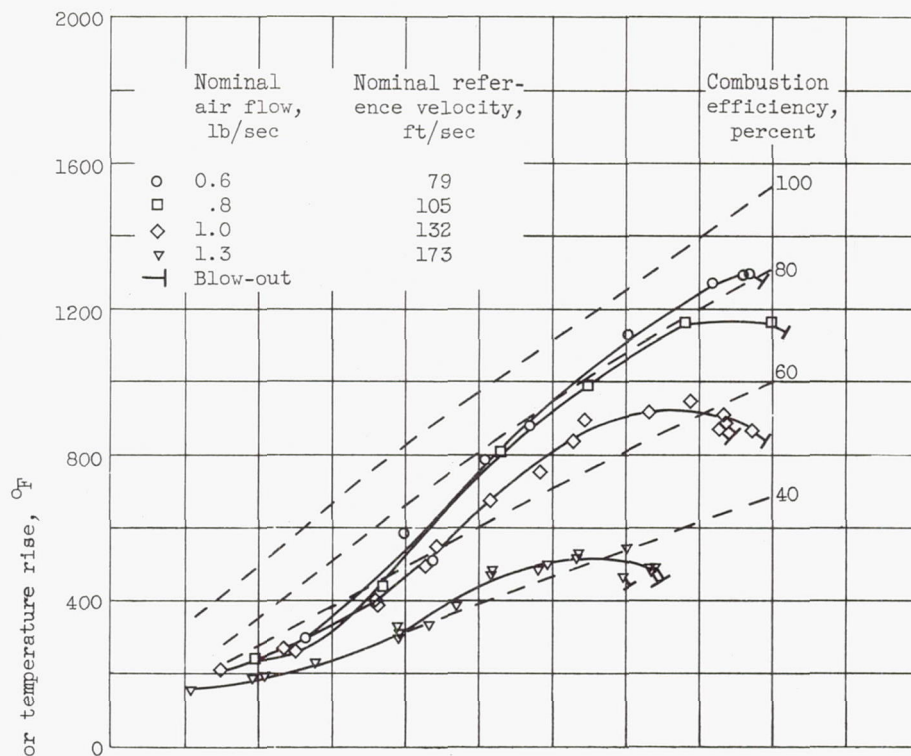
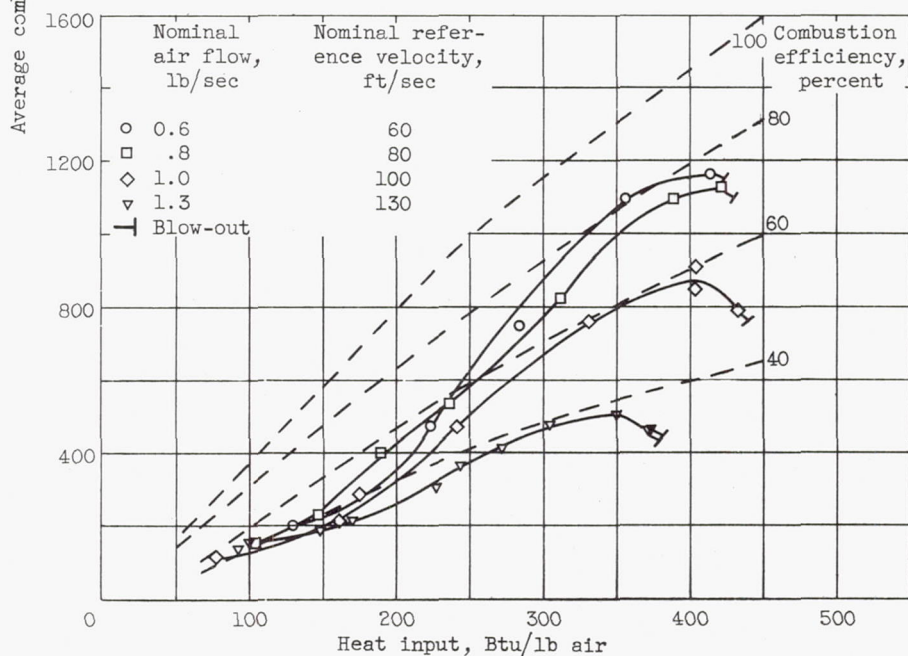
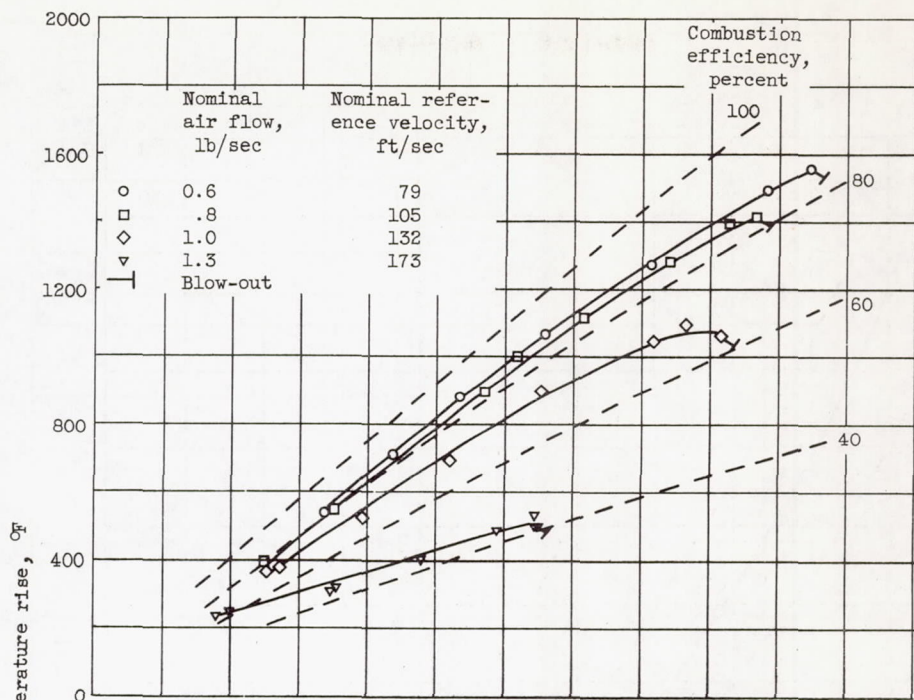
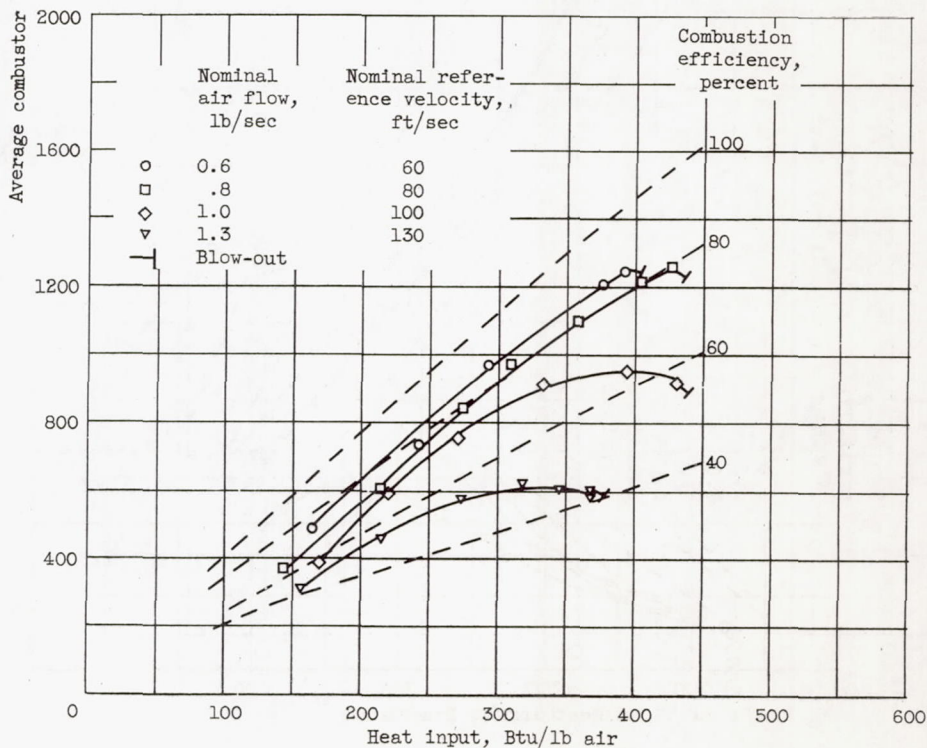
(a) Inlet-air temperature, 200°F (b) Inlet-air temperature, 40°F .

Figure 11. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, acetone.



(a) Inlet-air temperature, 200° F.



(b) Inlet-air temperature, 40° F.

Figure 12. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, diethyl ether.

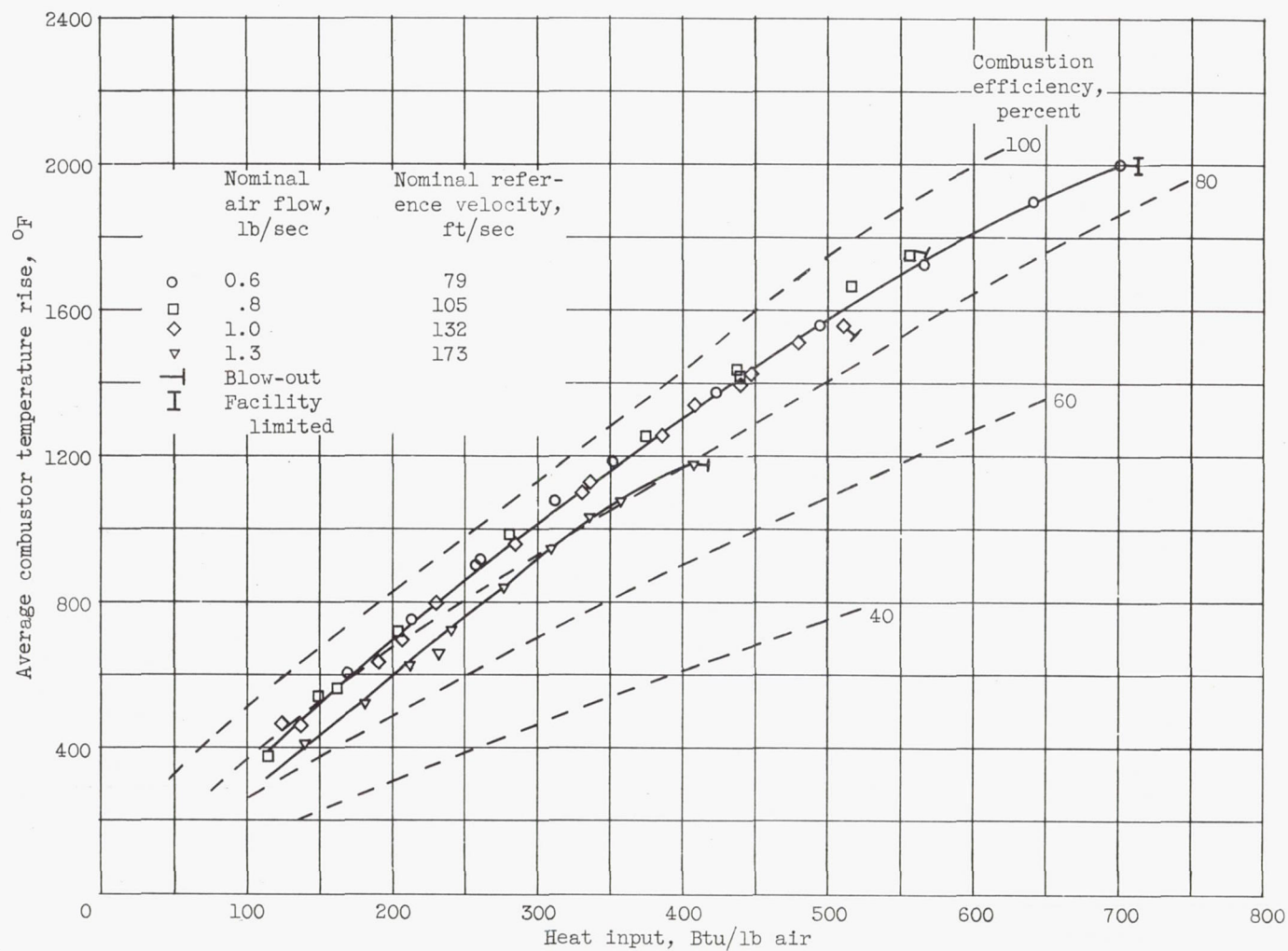
(a) Inlet-air temperature, 200°F .

Figure 13. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, propylene oxide.

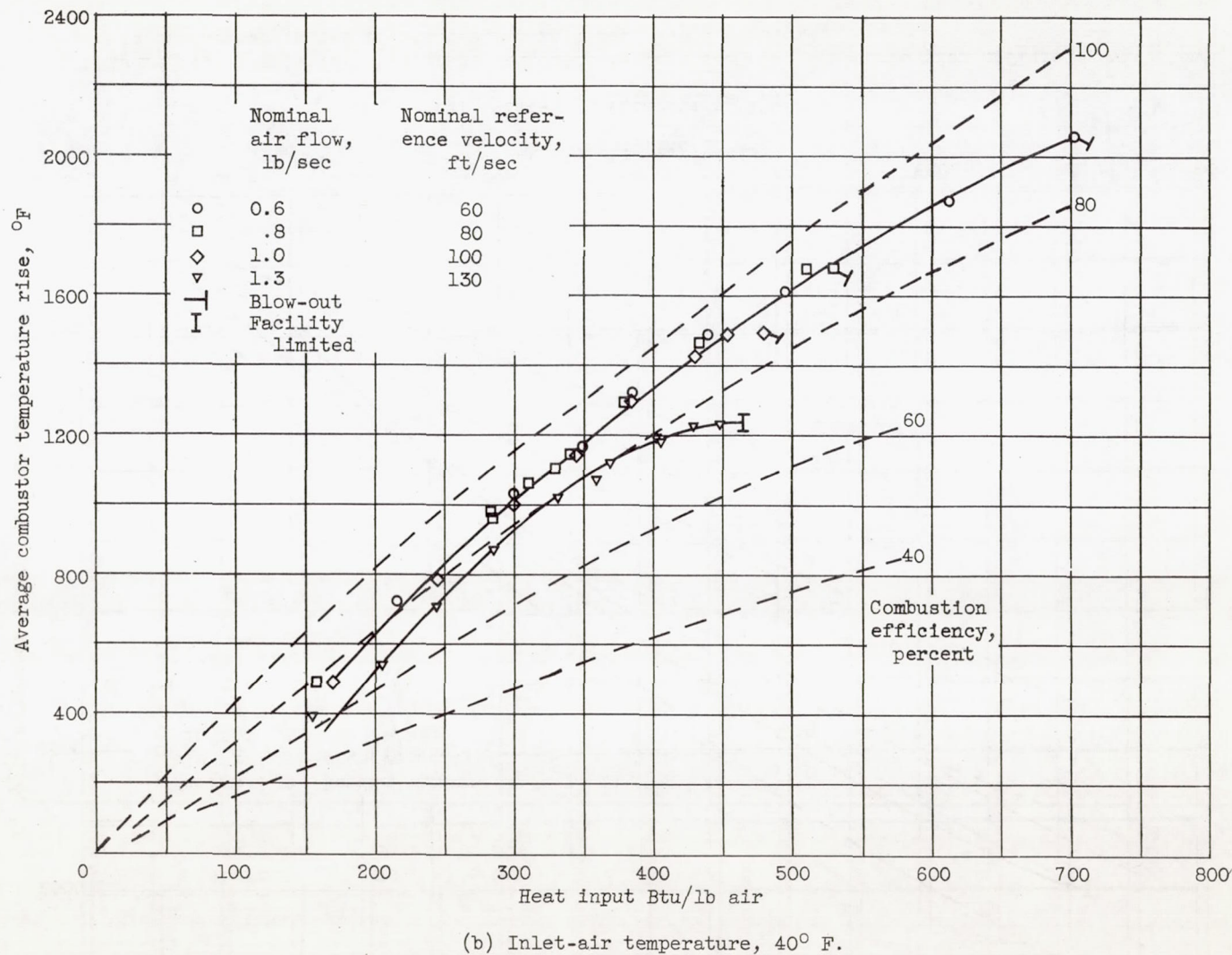
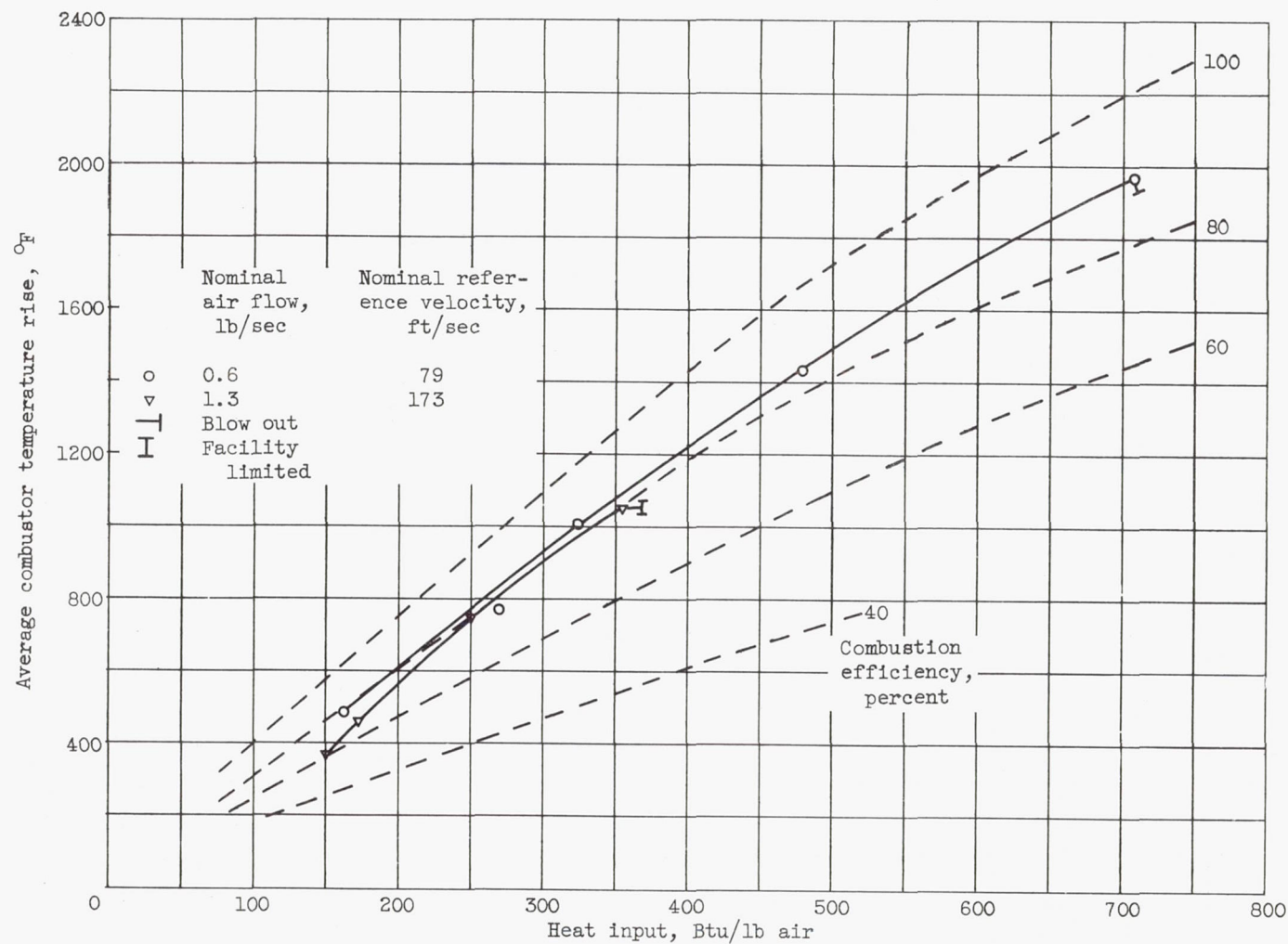
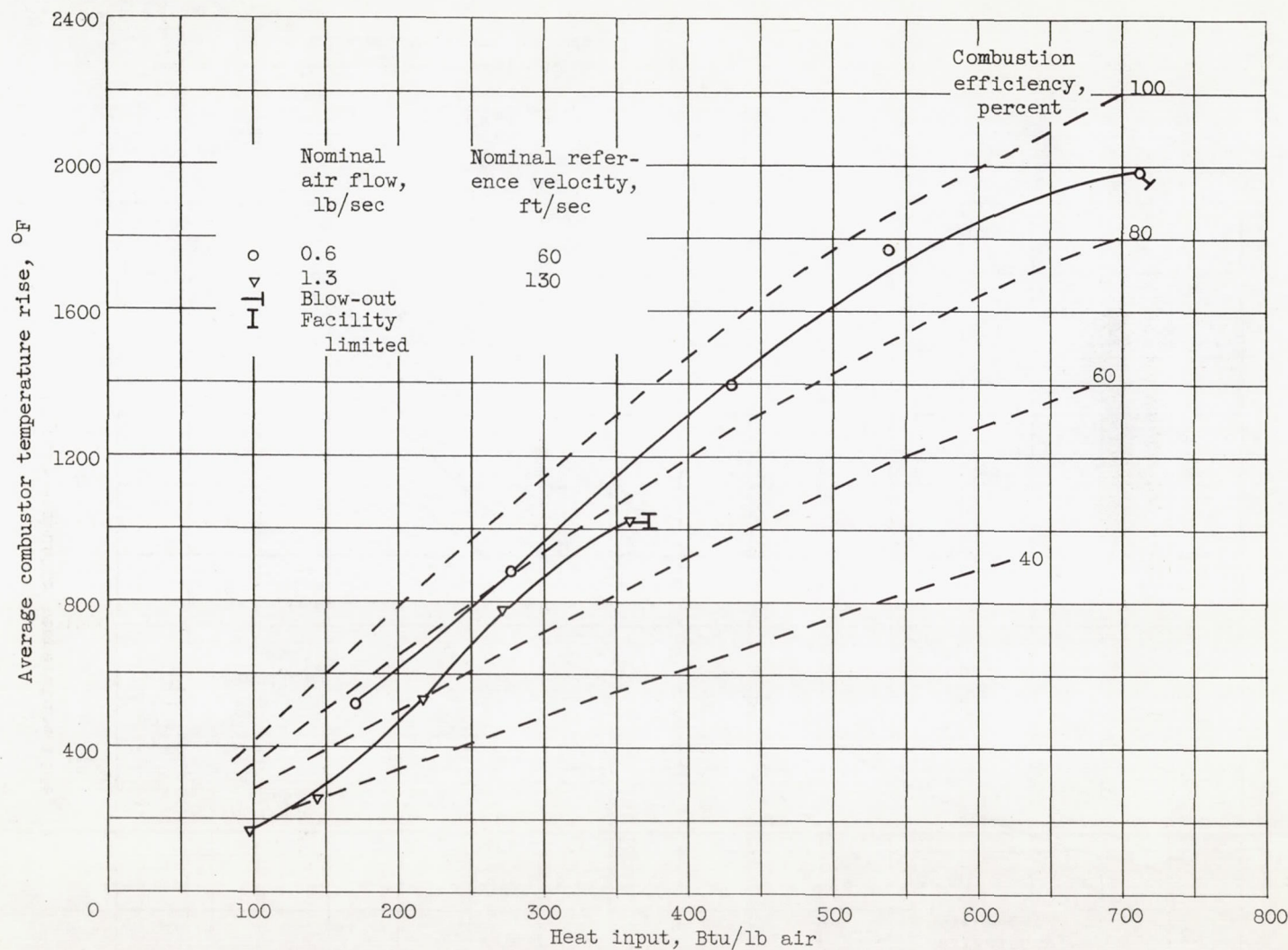


Figure 13. - Concluded. Variation of average combustor temperature rise and combustion efficiency with heat input for four of inlet-air mass flow. Fuel, propylene oxide.



(a) Inlet-air temperature, 200° F.

Figure 14. - Variation of average combustor temperature rise and combustion efficiency with heat input for two values of inlet-air mass flow. Fuel, acrolein.



(b) Inlet-air temperature, 40° F.

Figure 14. - Concluded. Variation of average combustor temperature rise and combustion efficiency with heat input for two values of inlet-air mass flow. Fuel, acrolein.

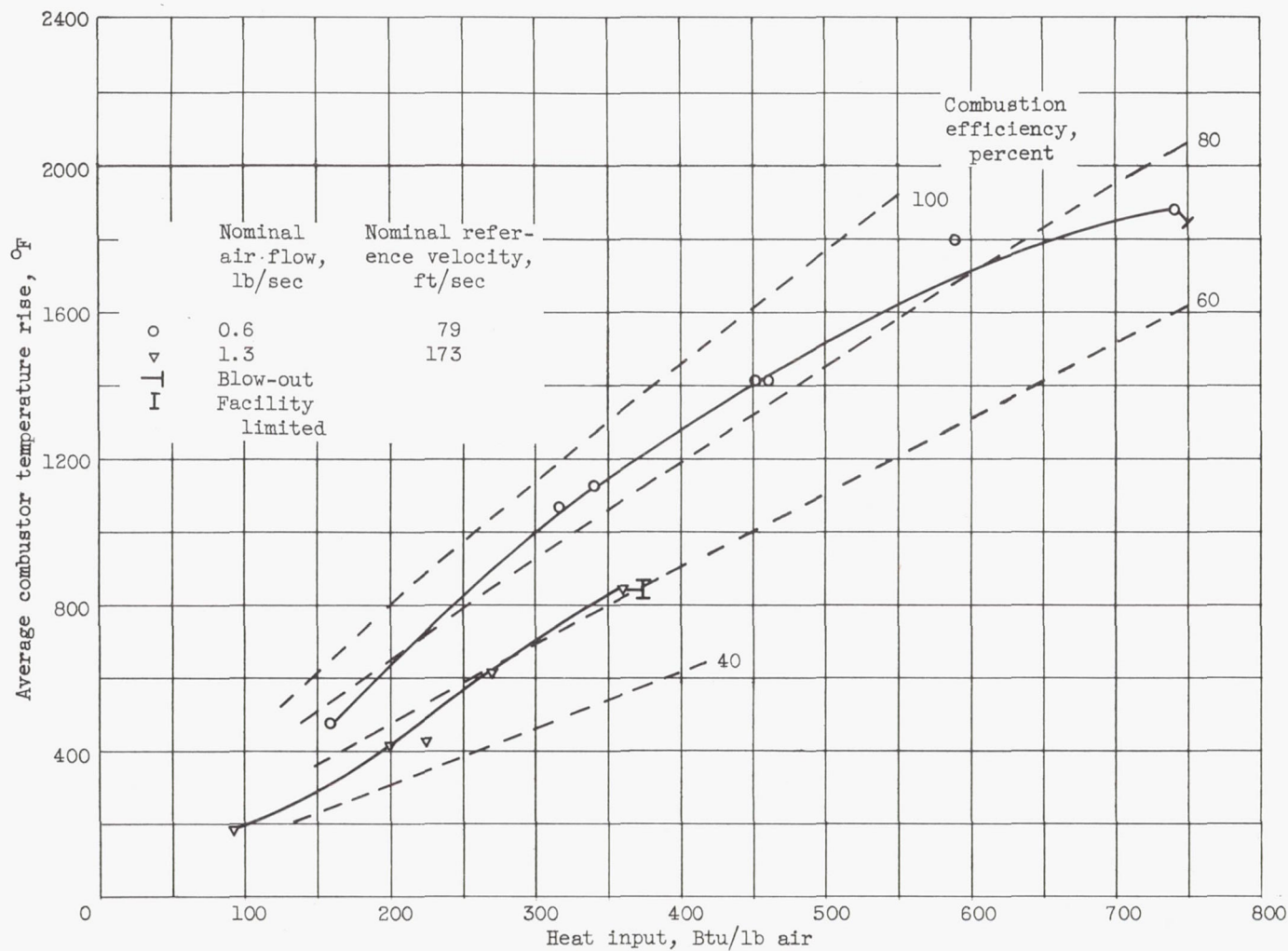
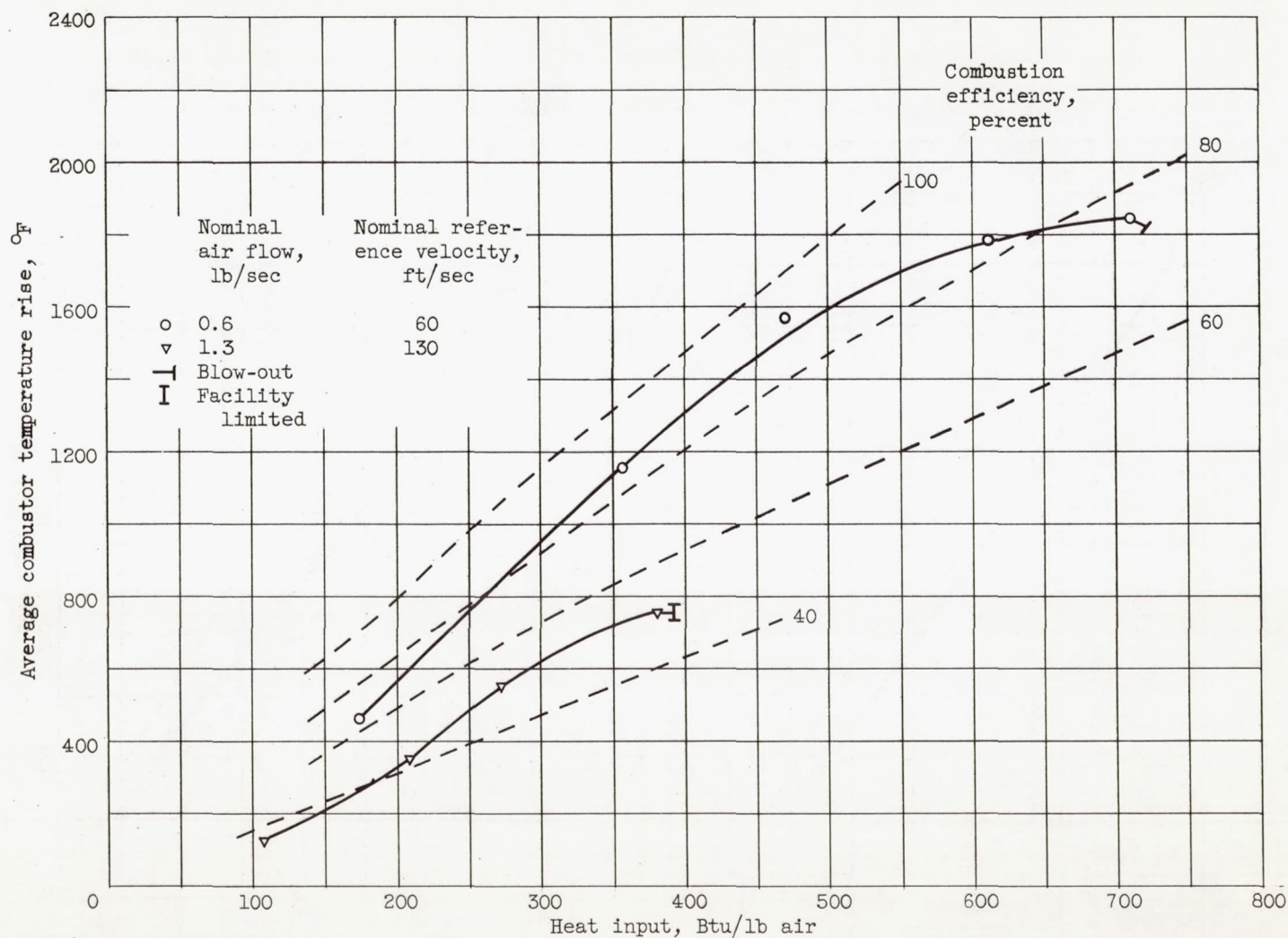
(a) Inlet-air temperature, 200°F .

Figure 15. - Variation of average combustor temperature and combustion efficiency with heat input for two values of inlet-air mass flow. Fuel, acrylonitrile.



(b) Inlet-air temperature, 40° F.

Figure 15. - Concluded. Variation of average combustor temperature and combustion efficiency with heat input for two values of inlet-air mass flow. Fuel, acrylonitrile.

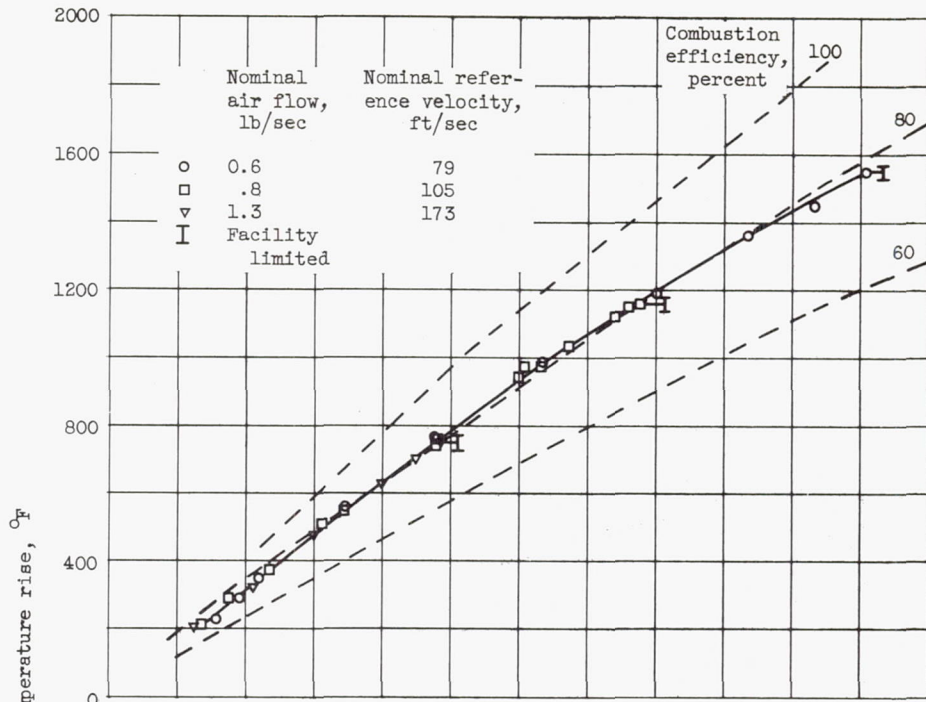
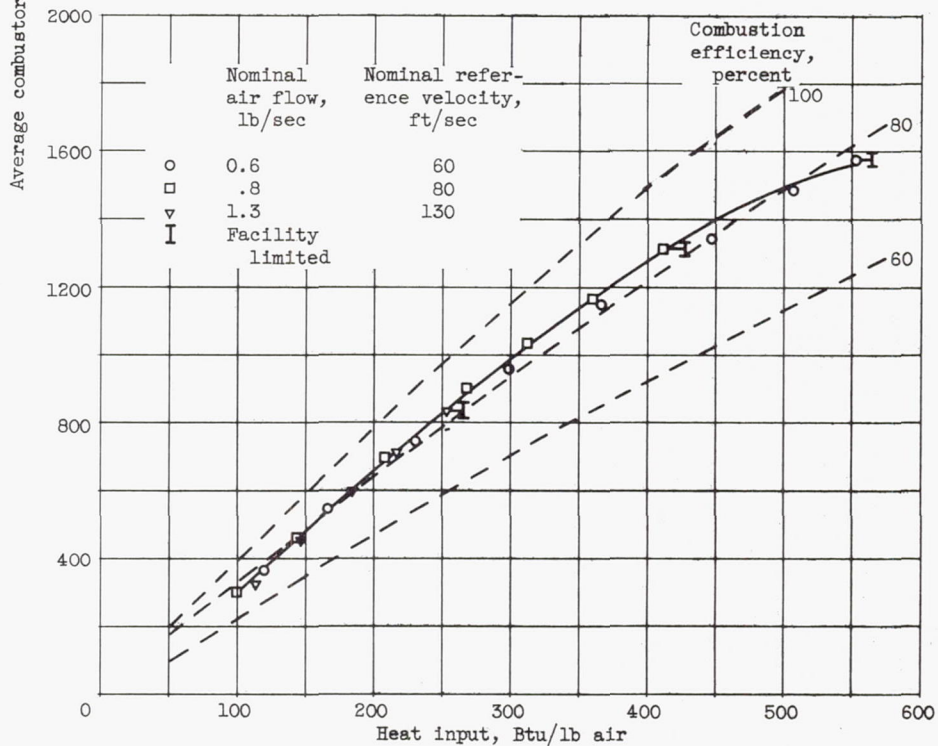
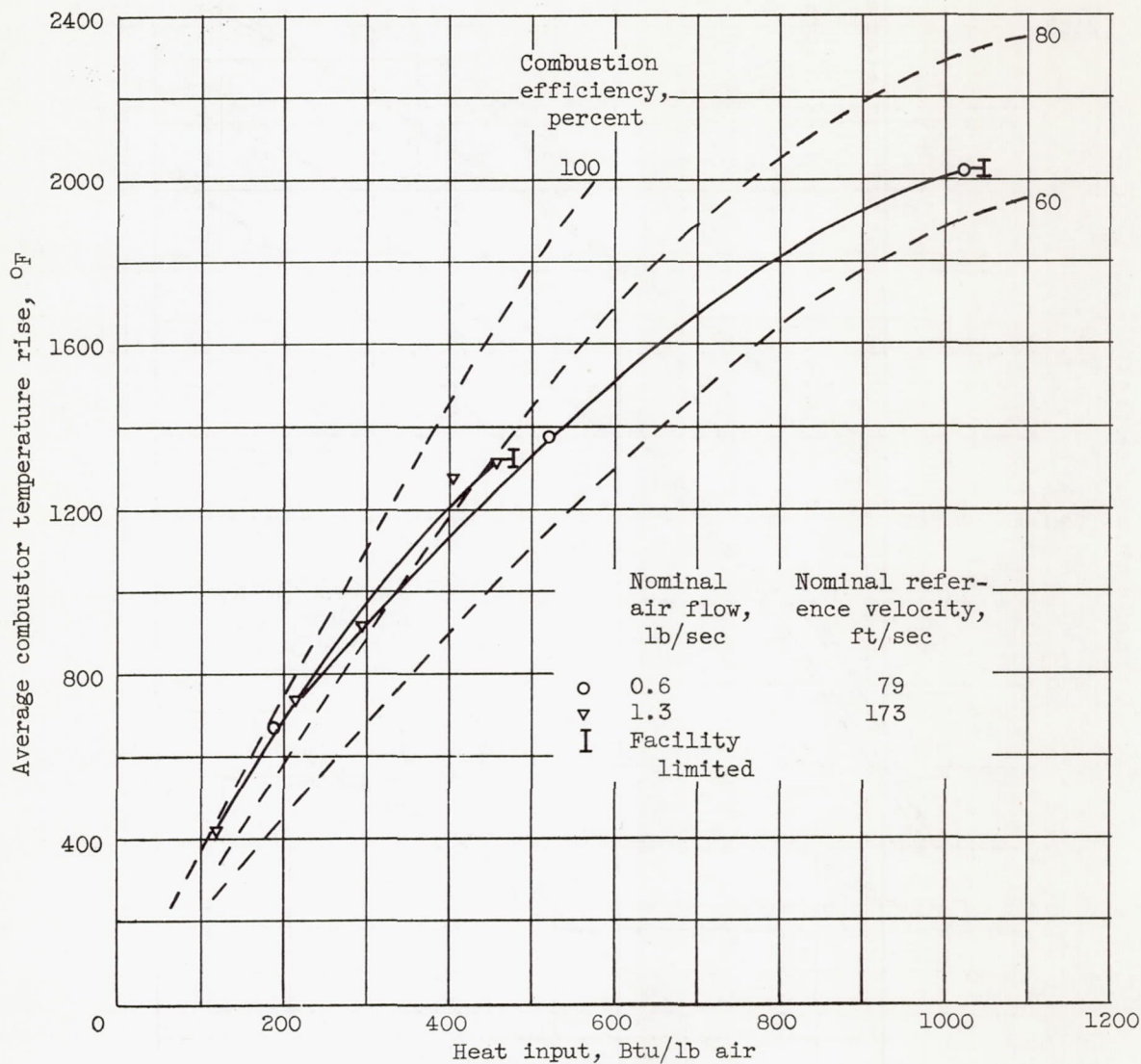
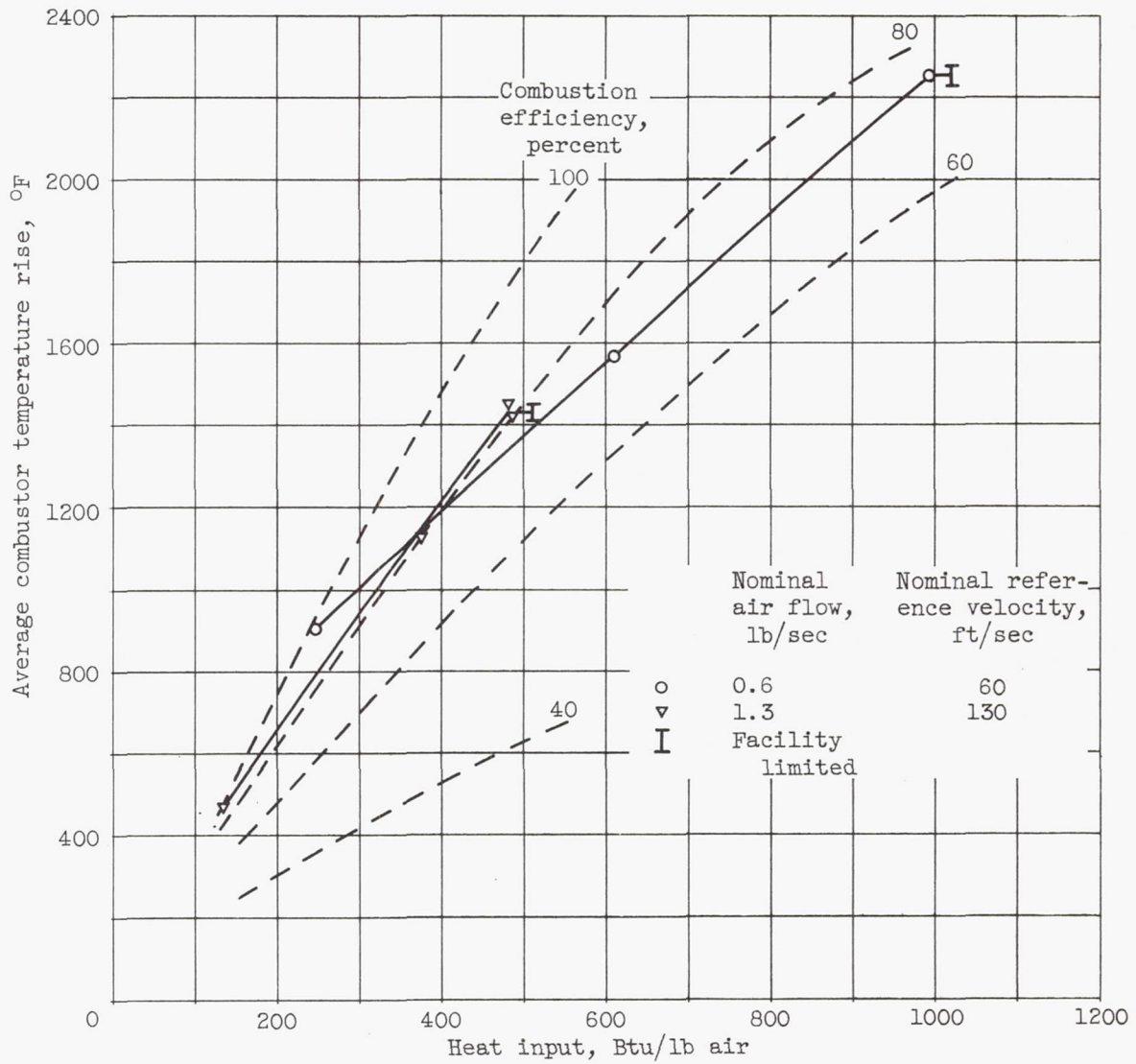
(a) Inlet-air temperature, 200°F .(b) Inlet-air temperature, 40°F .

Figure 16. - Variation of average combustor temperature rise and combustion efficiency with heat input for three values of inlet-air mass flow. Fuel, carbon disulfide.



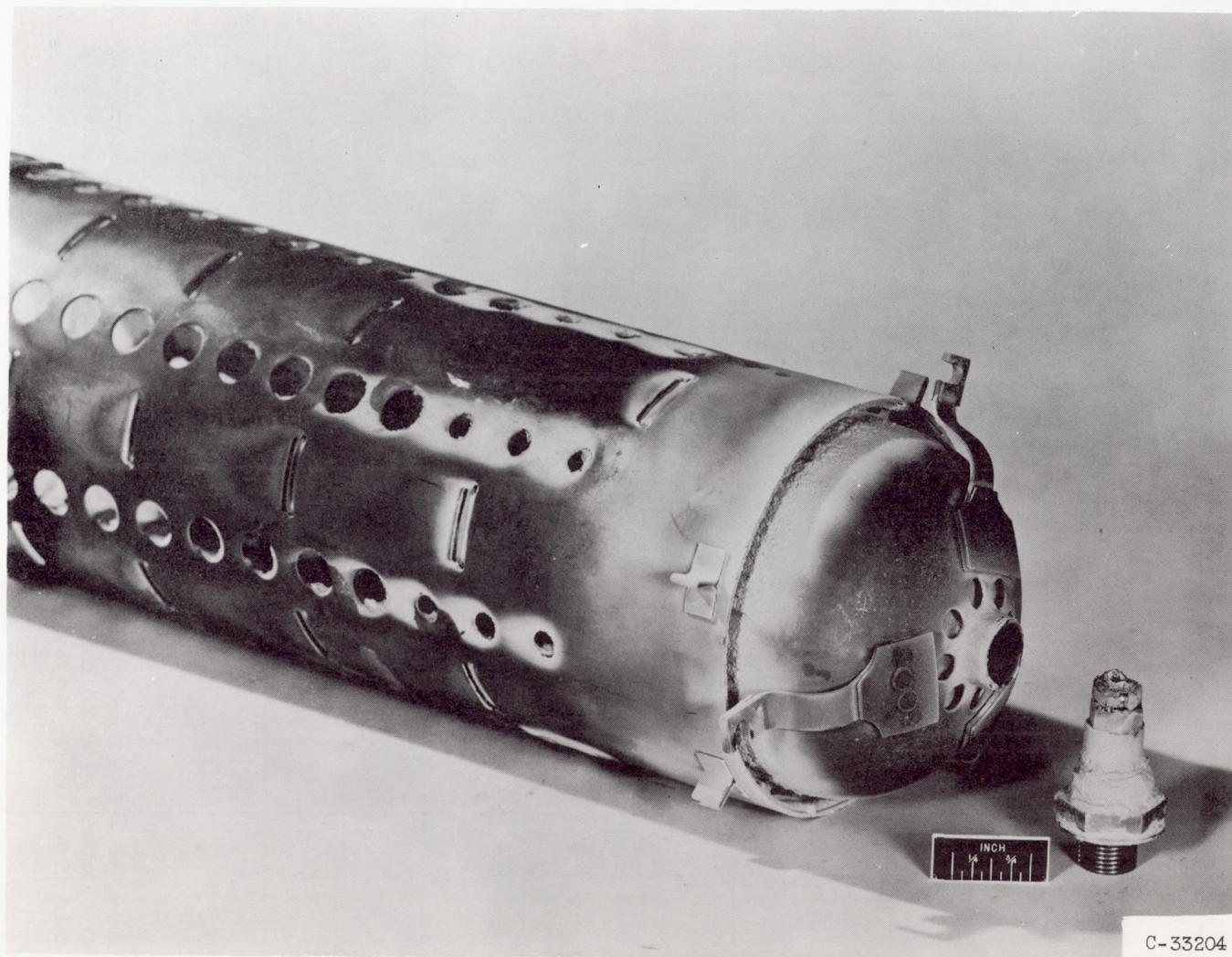
(a) Inlet-air temperature, 200° F.

Figure 17. - Variation of average combustor temperature rise and combustion efficiency with heat input for two values of inlet-air mass flow. Fuel, butylsilane.



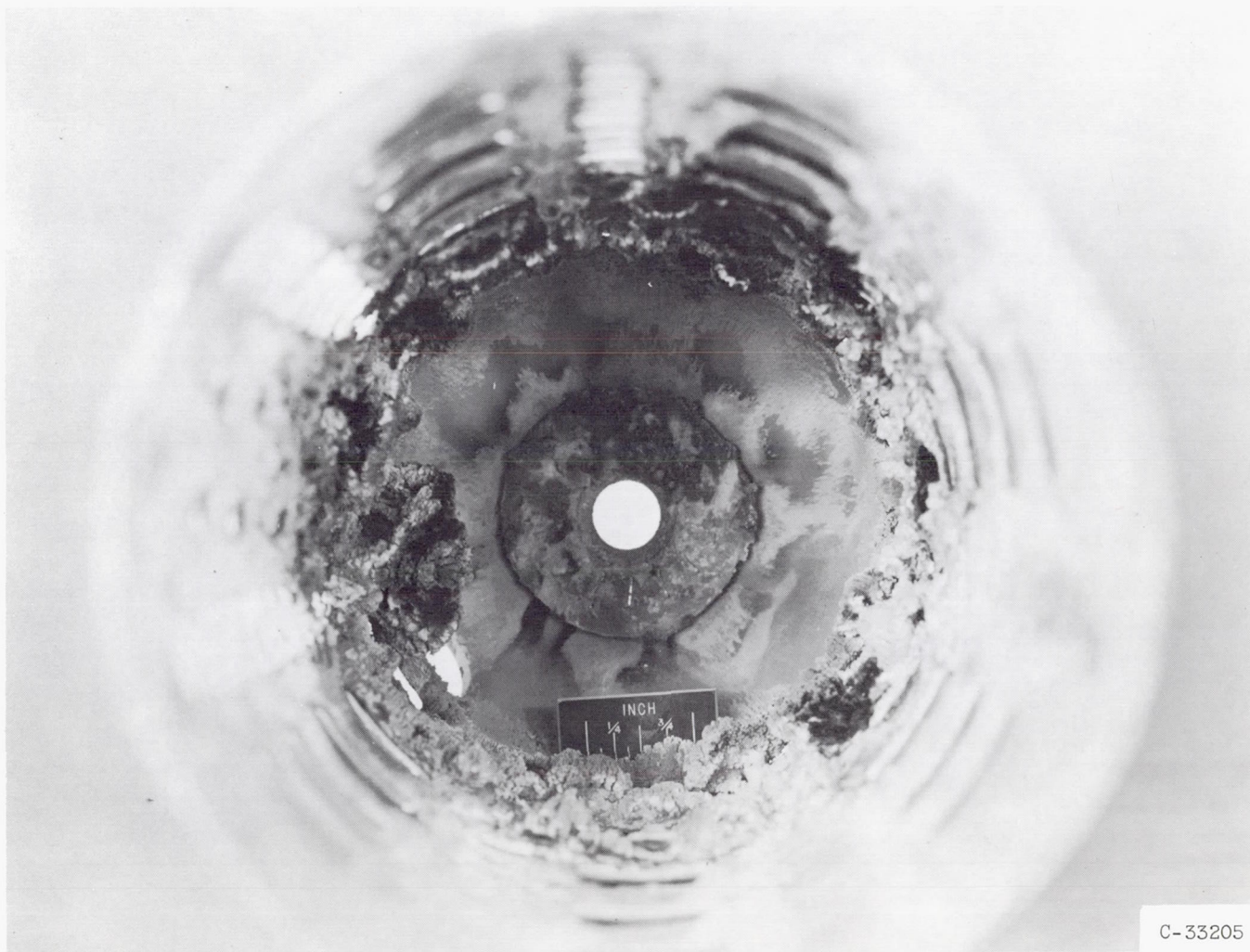
(b) Inlet-air temperature, 40° F.

Figure 17. - Concluded. Variation of average combustor temperature rise and combustion efficiency with heat input for two values of inlet-air mass flow. Fuel, butylsilane.



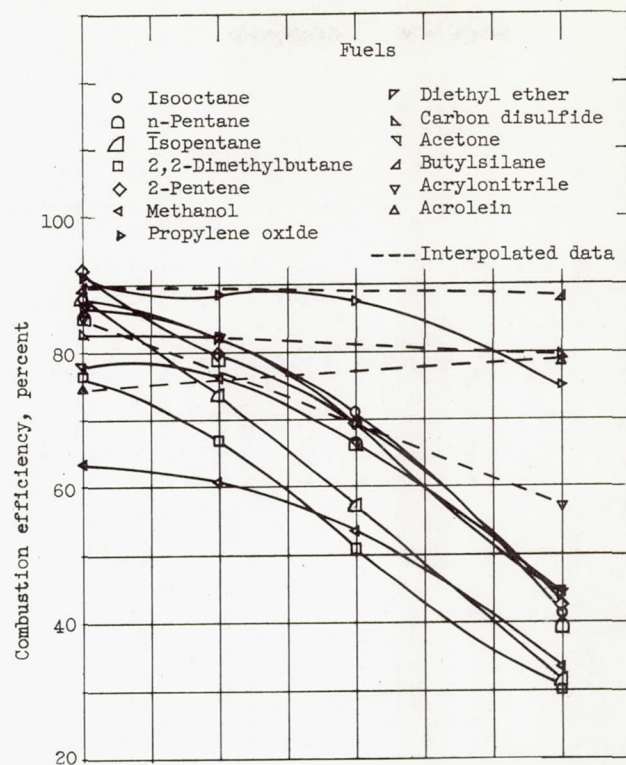
(a) Side view of combustion-chamber liner and fuel nozzle.

Figure 18. - Silicon deposits in J33 combustor resulting from use of butylsilane fuel.

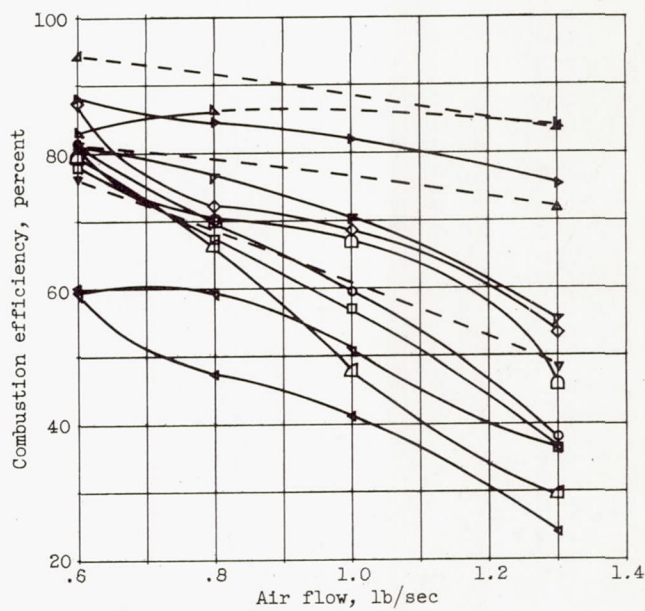


(b) Upstream of combustion-chamber liner.

Figure 18. - Concluded. Silicon deposits in J33 combustor resulting from use of butylsilane fuel.



(a) Inlet-air temperature, 200° F.



(b) Inlet-air temperature, 40° F.

Figure 19. - Variation of combustion efficiency at heat-input value of 250 Btu per pound of air with inlet-air mass flow and inlet-air temperature for five hydrocarbon, four oxygenated hydrocarbon, and four substituted hydrocarbon fuels.

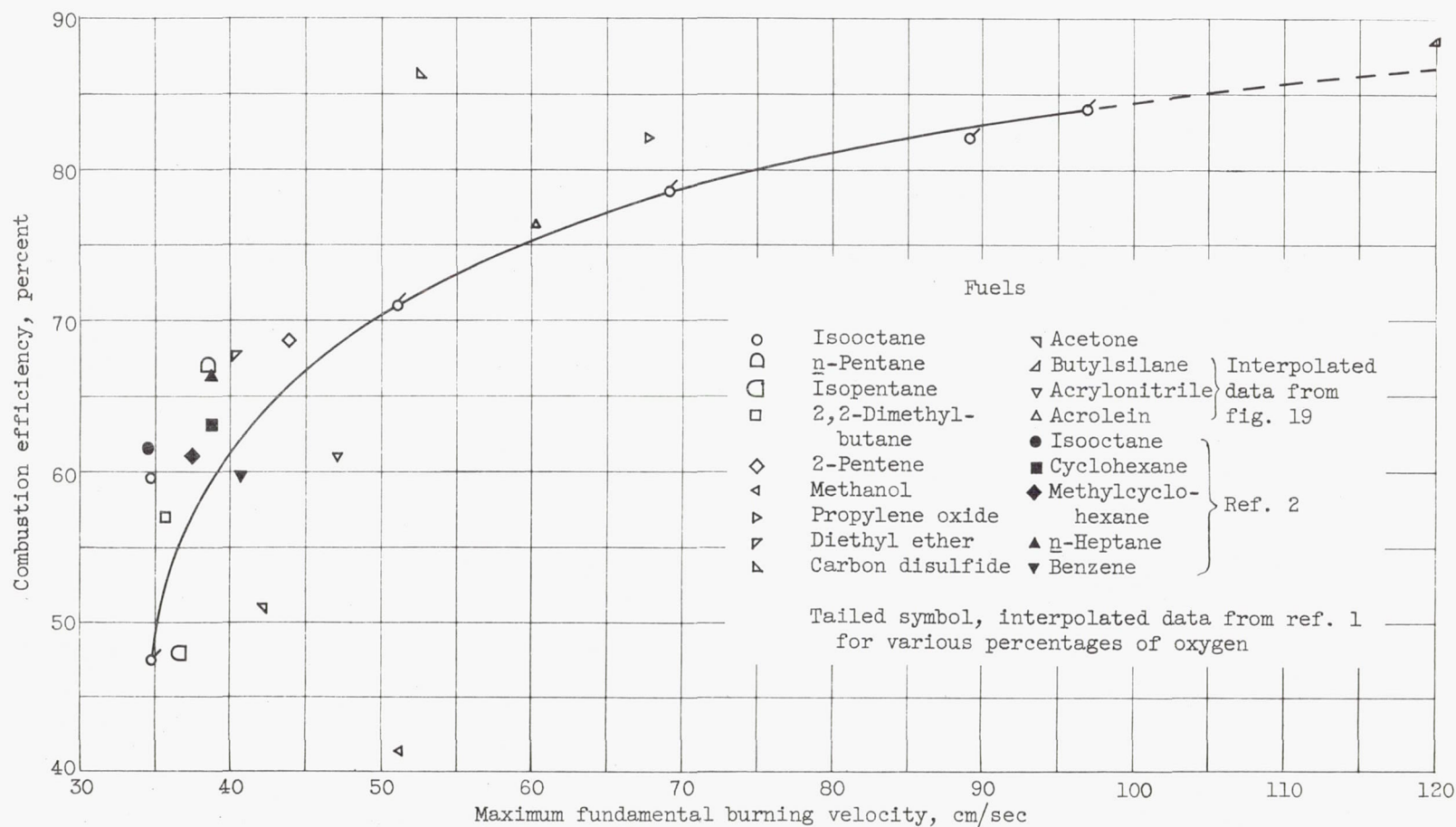
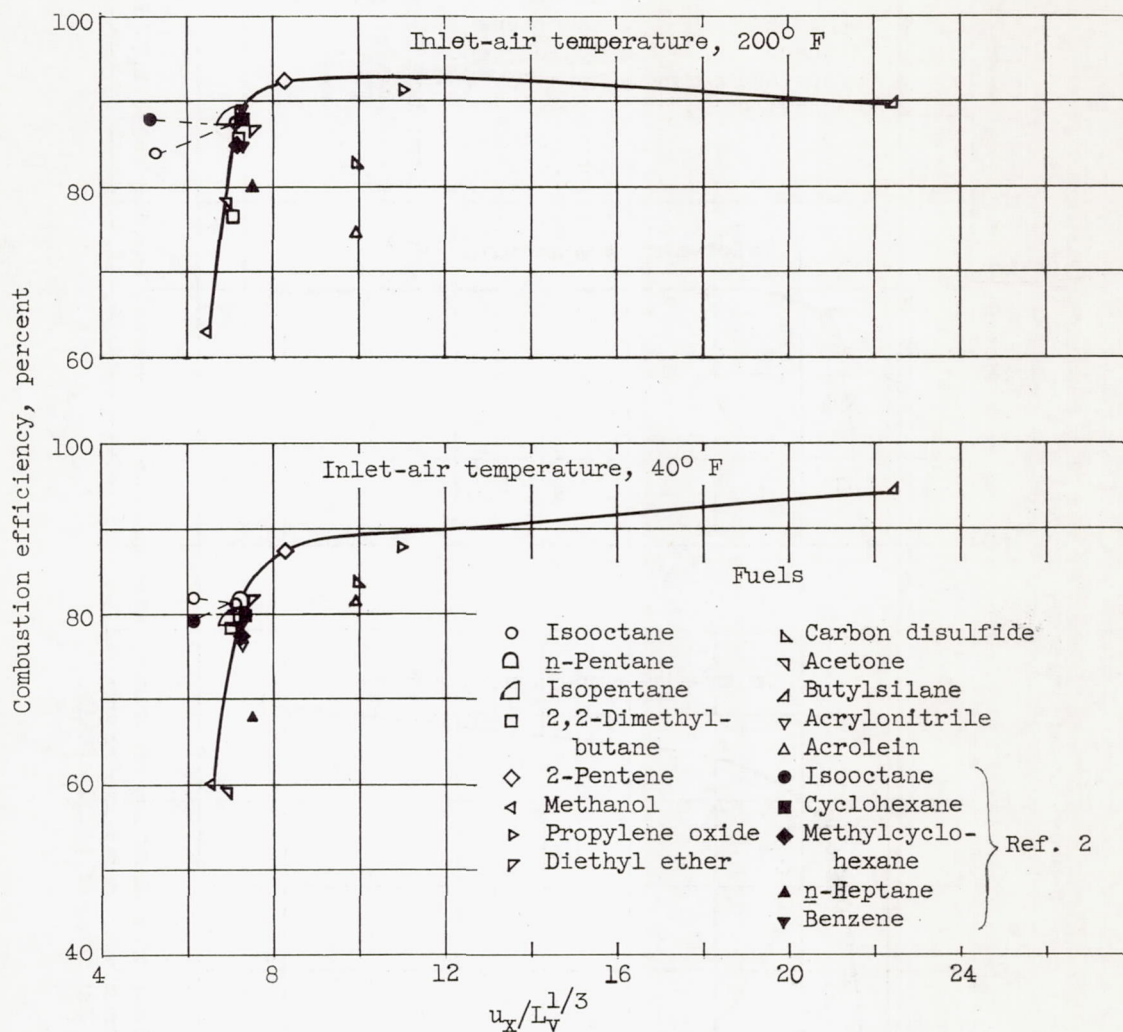
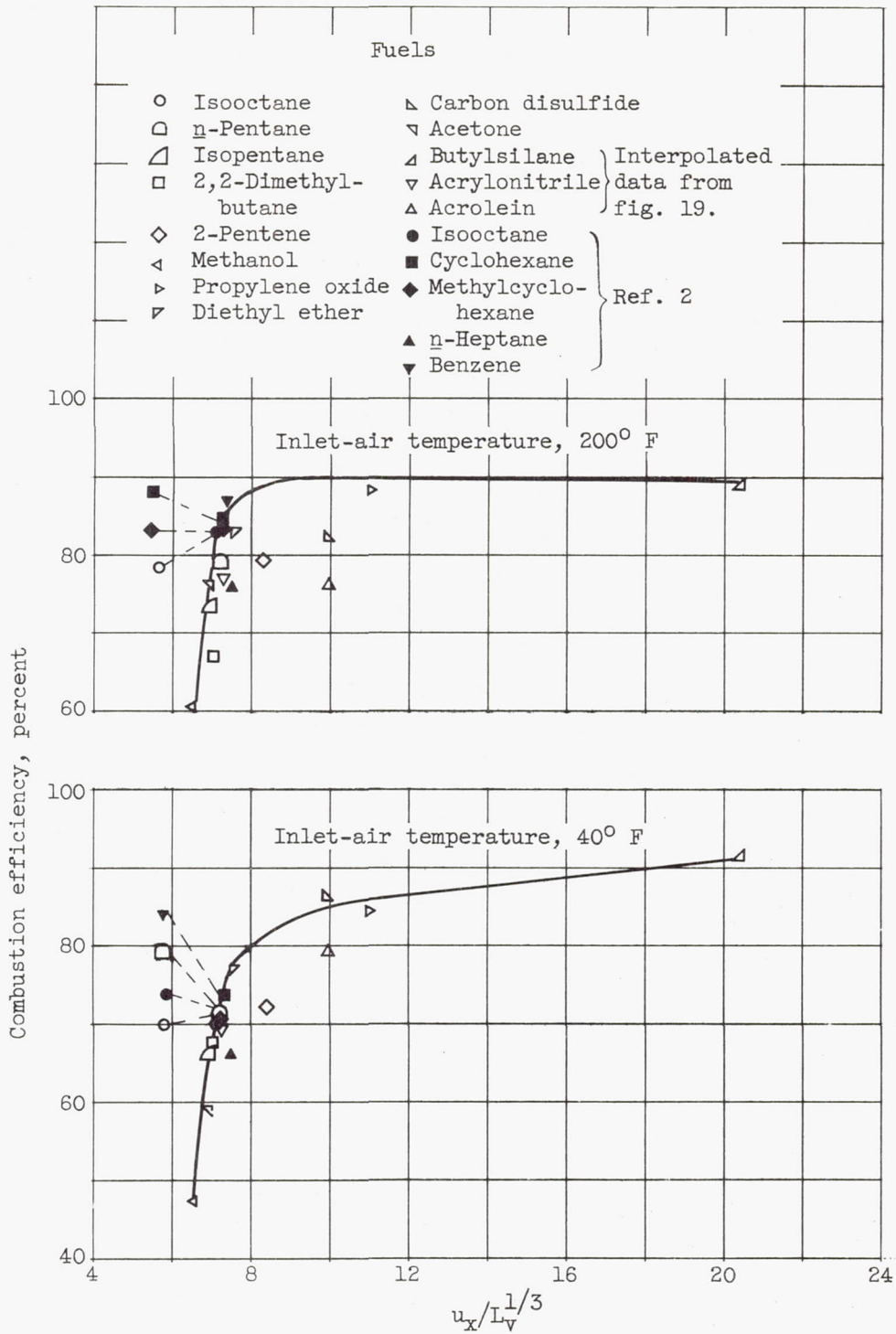


Figure 20. - Comparison of combustion efficiency with maximum fundamental burning velocity. Inlet-air temperature, 40° F; inlet-air flow, 1.0 pounds per second; inlet pressure, 14.3 inches of mercury absolute; heat-input value, 250 Btu per pound of air.



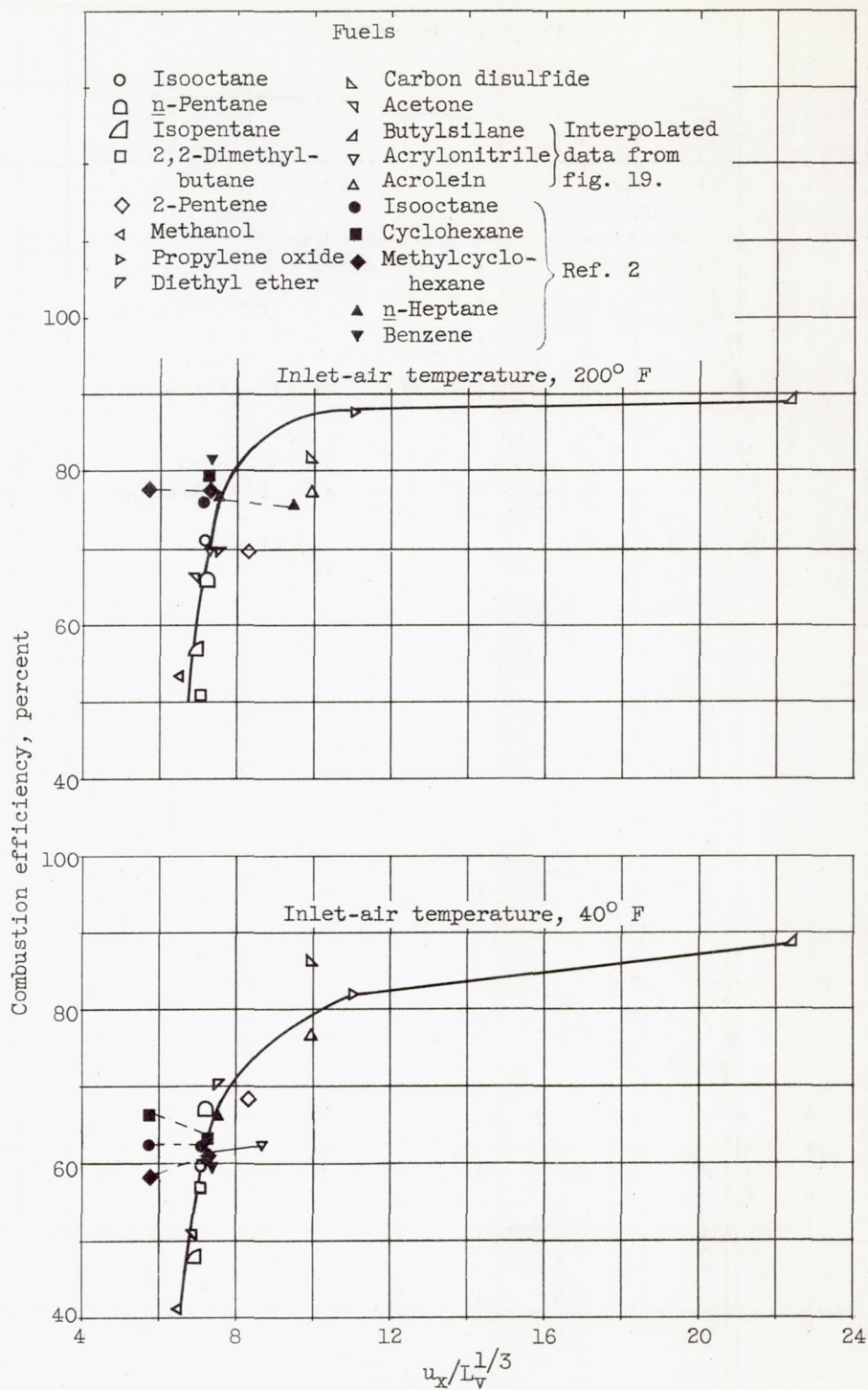
(a) Air flow, 0.6 pound per second.

Figure 21. - Variation of combustion efficiency. Heat input, 250 Btu per pound of air.



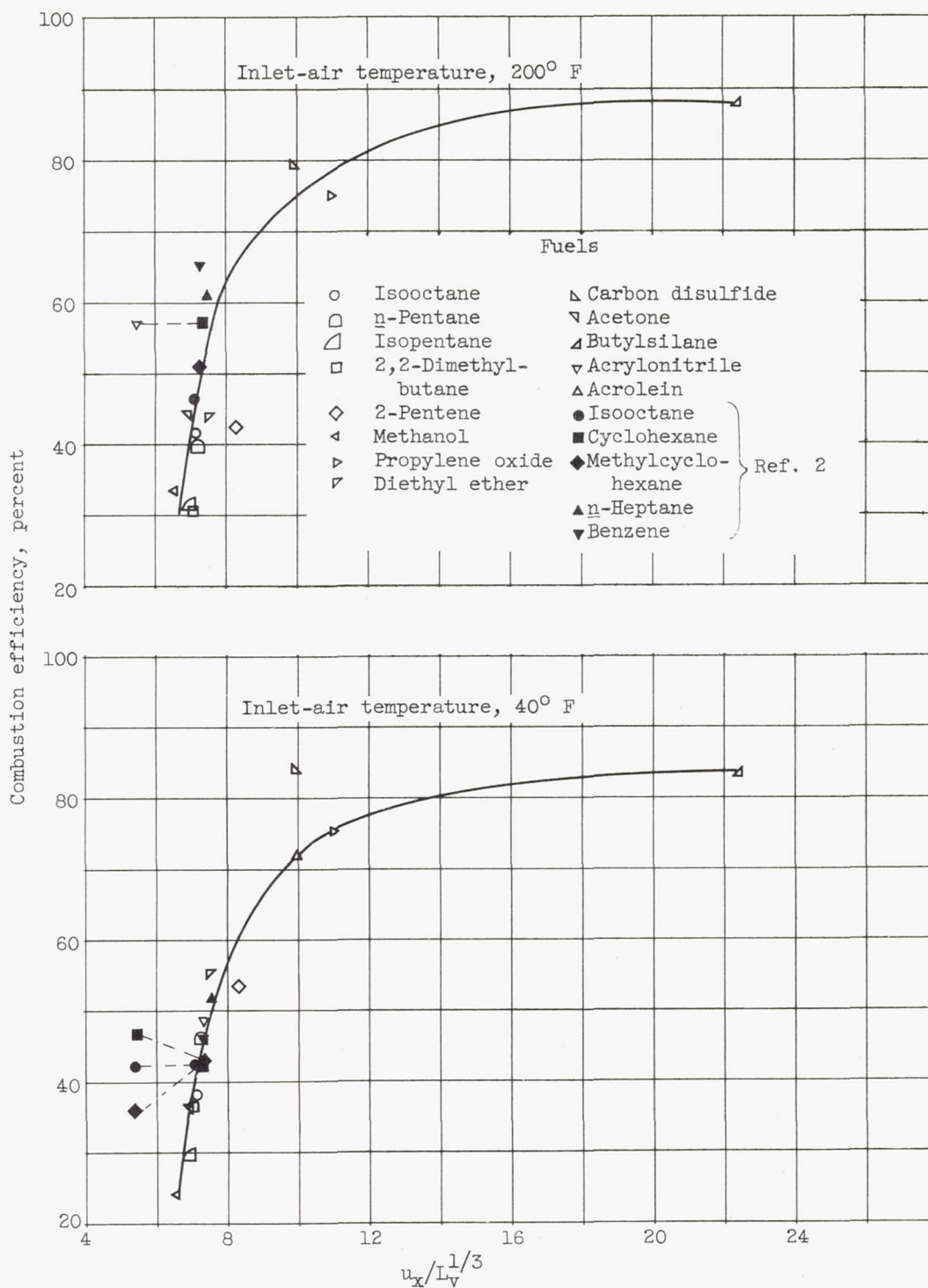
(b) Air flow, 0.8 pound per second.

Figure 21. - Continued. Variation of combustion efficiency.
Heat input, 250 Btu per pound of air.



(c) Air flow, 1.0 pounds per second.

Figure 21. - Continued. Variation of combustion efficiency.
Heat input, 250 Btu per pound of air.



(d) Air flow, 1.3 pounds per second.

Figure 21. - Concluded. Variation of combustion efficiency. Heat input, 250 Btu per pound of air.

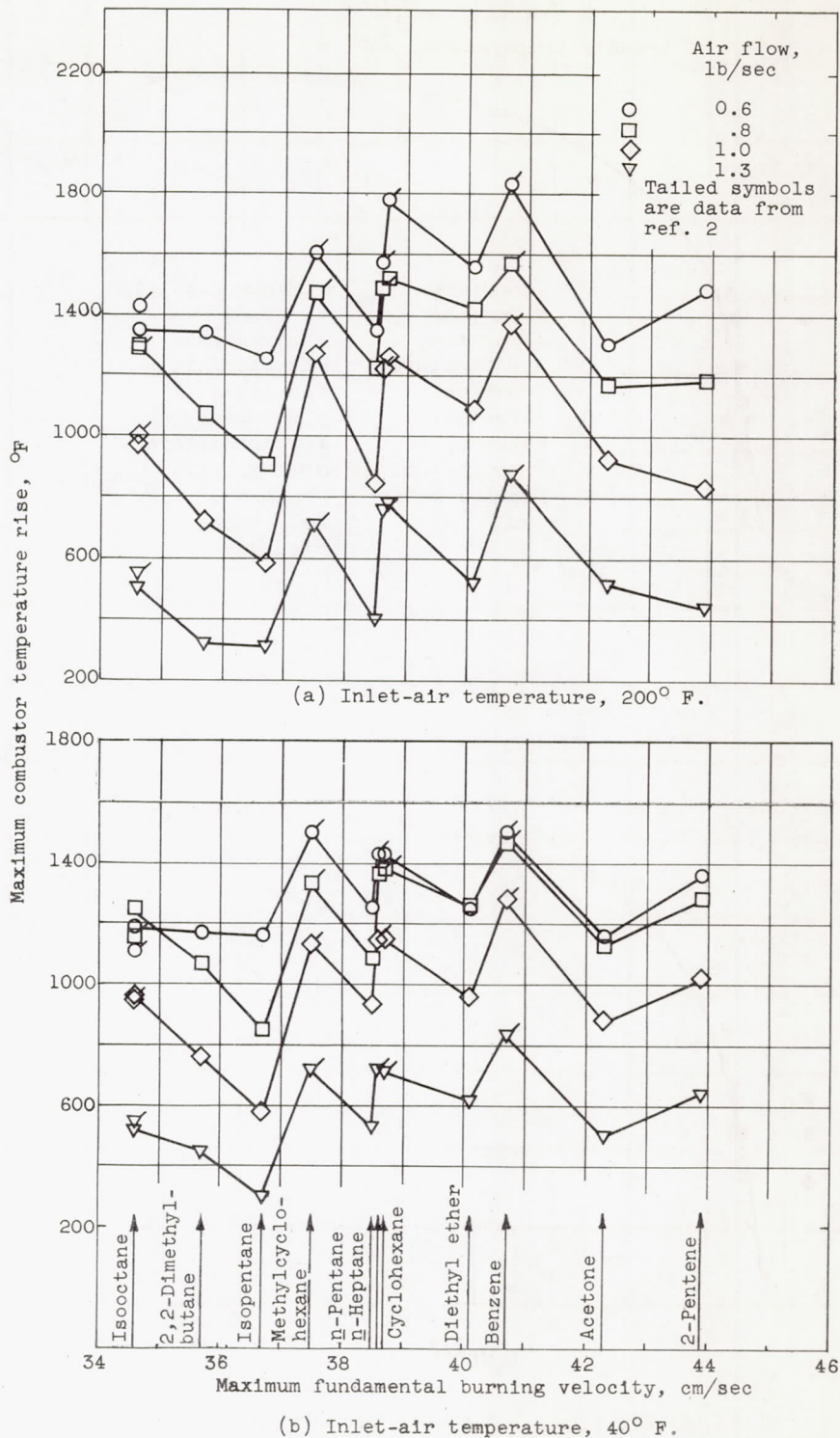


Figure 22. - Comparison of maximum combustor temperature rise with maximum fundamental burning velocity for nine hydrocarbon and two oxygenated hydrocarbon fuels. Inlet-air pressure, 14.3 inches of mercury absolute.